WASPS

SOCIAL *and* SOLITARY

GEORGE W. &
ELIZABETH G.
PECKHAM

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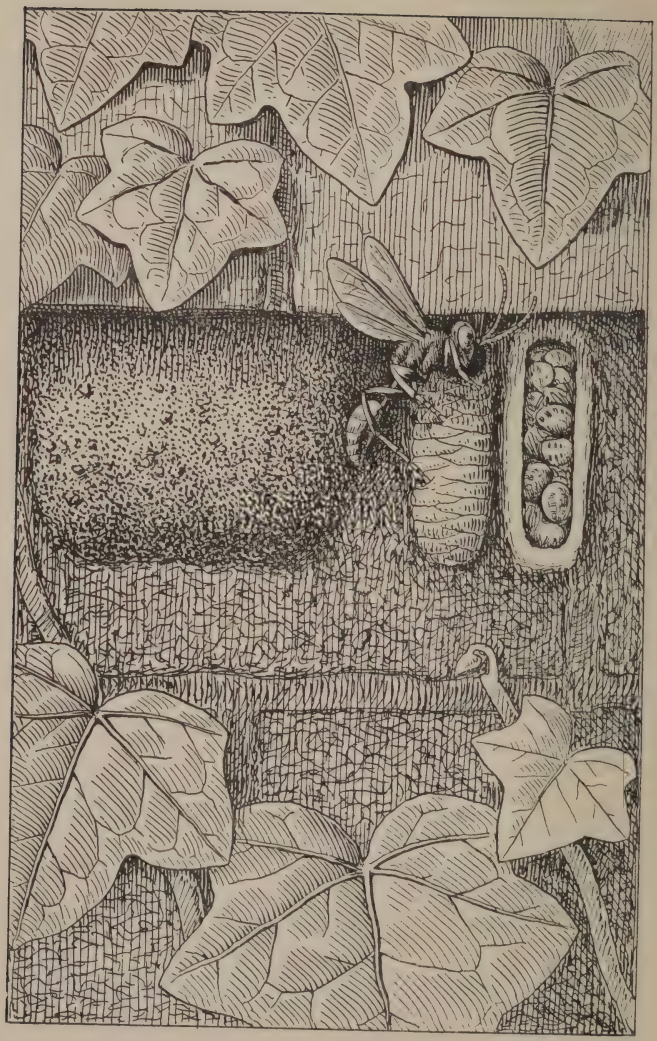

Page 266

PELOPÆUS ON NEST, GROUP OF FINISHED CELLS, AND TUBE OPENED TO SHOW SPIDERS

WASPS
SOCIAL AND SOLITARY

BY

GEORGE W. PECKHAM
AND
ELIZABETH G. PECKHAM

WITH AN INTRODUCTION BY
JOHN BURROUGHS

ILLUSTRATIONS BY JAMES H. EMERTON

"Bold sons of air and heat, untamed, untired." — ILIAD, Book XVII

BOSTON AND NEW YORK
HOUGHTON, MIFFLIN AND COMPANY
The Riverside Press, Cambridge
1905

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Published April, 1905

NOTE

A PART of the matter presented in this volume was published several years ago by the Wisconsin Biological Survey, under the title "Instincts and Habits of the Solitary Wasps." These chapters have been revised and modified, and new matter based upon later work has been added, in the hope that in their present less technical form the observations recorded will be of interest to the general reader.

For a number of the text cuts used in this volume we are indebted to the courtesy of Dr. E. A. Birge, Director of the Wisconsin Geological and Natural History Survey.

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Introduction

NOT long since I wrote to a friend, a nature lover, as follows: "The most charming monograph in any department of our natural history that I have read in many a year is on our solitary wasps, by George W. Peckham and his wife, of Wisconsin, — a work so delightful and instructive that it is a great pity it is not published in some popular series of nature books, where it could reach its fit audience, instead of being handicapped as a State publication." This end has now been brought about, and the book — revised and enlarged with much new material and many new illustrations — placed within easy reach of all nature lovers, to whom it gives me pleasure to commend it. It is a wonderful record of patient, exact, and loving observation, which has all the interest of a romance. It opens up a world of Lilliput right at our feet, wherein the little people amuse and delight us with their curious human foibles and whimsicalities, and surprise us with their intelligence and individuality. Here I had been saying in print that I looked upon insects as perfect automata, and all of the same class as nearly alike as the leaves of the trees or

the sands upon the beach. I had not reckoned with the Peckhams and their solitary wasps. The solitary ways of these insects seem to bring out their individual traits, and they differ one from another, more than any other wild creatures known to me. It has been thought that man is the only tool-using animal, yet here is one of these wasps, Ammophila, that uses a little pebble to pound down the earth over her nest. She takes the pebble in her mandibles, as you or I would take a stone in our hand, and uses it as a hammer to pound down the soil above the cavity that holds her egg. This is a remarkable fact; so far as I know there is no other animal on this continent that makes any mechanical use of an object or substance foreign to its own body in this way. The act stamps Ammophila as a tool-using animal.

I am free to confess that I have had more delight in reading this book than in reading any other nature book in a long time. Such a queer little people as it reveals to us, so whimsical, so fickle, so fussy, so forgetful, so wise and yet so foolish, such victims of routine and yet so individual, with such apparent foresight and yet such thoughtlessness, finding their way back to the same square inch of earth in the monotonous expanse of a wide plowed field with unfailing accuracy, and then at times finishing their cell and sealing it up without the

spider and the egg; hardly any two alike; one nervous and excitable, another calm and unhurried; one careless in her work, another neat and thorough; this one suspicious, that one confiding; one species digging its burrow before it captures its game, others capturing the game and then digging the hole; one wasp hanging its spider up in the fork of a weed to keep it away from the ants while it works at its nest, and then running to it every moment or two to see that it is safe; another laying the insect on the ground while it digs, — verily a queer little people, with a lot of wild nature about them, and of human nature, too.

JOHN BURROUGHS.

WASPS
Social and Solitary

Chapter I

COMMUNAL LIFE

"For where's the state beneath the firmament
That doth excel the wasps' for government."

"What is not good for the swarm is not good for the wasp."

As the tendency of mankind to crowd into towns grows stronger the joys of country life and the workings of Nature are more and more excluded from the daily experience of humanity. In a few the primal love of the wild is too strong for suppression, and turning from the hot and noisy streets they find it a refreshment of spirit to meet our little brothers of earth and air in the wider spaces of their own territory.

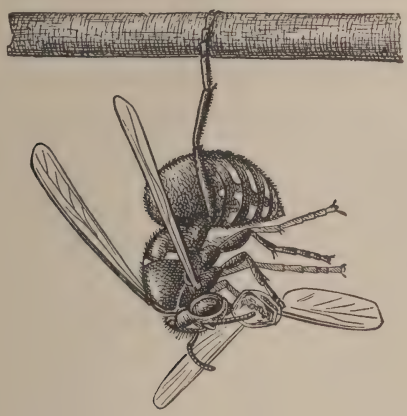
We were walking through the woods one hot day in the middle of August when our attention was attracted by a stream of yellow-jackets issuing from the ground. They came in such surprising numbers and looked so

full of energy that we stopped to watch them, and this was our introduction to the study of these "bold sons of air and heat," although a perusal of Fabre's fascinating "Souvenirs Entomologiques" had prepared us to feel a lively interest in them. We were at our summer home near Milwaukee, where meadow and garden, with the wooded island in the lake close by, offered themselves as hunting grounds, while wasps of every kind, the socialistic tribes as well as the extreme individualists of the solitary species, were waiting to be studied.

The Vespas that had aroused our interest received our first attention, and a nest in the ground proved to be a most convenient arrangement. Experiments that would have been dangerous to life and limb had we tried them with a paper nest hanging in the open, were easy here so long as we kept calm and unflurried. Intent upon their own affairs, and unsuspicious of evil, perhaps because they knew themselves to be armed against aggression, they accepted our presence, at first with indifference; but as we sat there day after day we must have become landmarks to them, and perhaps before the summer was over they considered us really a part of home.

While poor humanity takes comfort in a mid-day siesta, wasps love the heat of noontide, and with every rise in temperature they fly faster, hum louder, and

rejoice more and more in the fullness of life. The entrance to the Vespa nest was but an inch across; and once when they were going in and out in a hurrying throng, jostling each other in their eagerness, we counted the number that passed, one taking the entrances and one



WASP EATING

the exits. In ten minutes five hundred and ninety-two left the nest and two hundred and forty-seven went in, so that we saw eight hundred and thirty-nine or about eighty to the minute. This must be a strong swarm, wonderful indeed when we thought that it had all come from a single queen mother. We imagined how she had made an early start, digging a hole in the ground, building within it a paper comb with five or six cells around a

central column, and laying therein some neuter eggs; how she had then spent a month in attending carefully to the beginnings of things, feeding the young larvæ as they hatched, and watching over them through their childhood and youth; and then how her solicitude was rewarded by the filial devotion with which this first set of workers took upon themselves the labor of excavating, building, and feeding the young, everything indeed except the egg-laying. These queens, surrounded though they are by respectful and attentive subjects, have much the worst of it in our estimation, never going out, and passing their lives in a dull routine. Through the early summer only neuters are produced, but when fall approaches the future generation is provided for by the development of males and females. The activity of the little colony is limited by the season, for as the days grow colder the males and females leave the nest and mate, and a little later both males and workers lose ambition, become inactive and finally die, while the queens hide away in protected corners to reappear in the spring. The eggs and larvæ, left unfed and uncared for, become a prey to moulds and to hordes of insects, and thus the swarm comes to an end.

We had once made some not very successful attempts to find out whether spiders had a sense of color; and seeing

that the conditions were much more favorable with our present subjects, we thought it would be a good plan to test their knowledge of the spectrum. Providing six sheets of stiff paper two feet square, colored respectively red, blue, green, pink, and two shades of yellow, and cutting a circular hole four and one half inches in diameter in the centre of each, we began our experiments by placing the red paper over the nest so that the entrance was clearly exposed. The outgoing wasps dashed upward without noticing it, but great was the confusion among the homecomers. Thrown out of their reckoning, they clamored about us in ever increasing swarms. Like Homer's wasps,

> "All rise in arms and with a general cry
> Assert their domes and buzzing progeny,"

and a crisis (for us) was approaching, when one, a pioneer of thought, determined to go into the hole, which did not look like the right hole, although it was where the right hole ought to be; and so potent is example that one by one the others followed. Three hours later they had become accustomed to the change, and went in and out as usual.

They had noticed the paper; that was plain enough, but did they notice the redness? To test this, we left things as they were for two days, and then substituted

blue paper for the red. Again the confusion, the swarming of fervent legions, the noisy expostulations, the descent of one after another; but this time they settled down to their ordinary routine in a little more than two hours. On the following day we removed the blue paper, leaving the grass around the nest exposed; and this proved a new source of mystification, but not so serious as the others. At the end of an hour twenty-five or thirty were still buzzing about, needing the guidance of the blue paper to get inside, and entering at once when it was replaced. As we tried new colors from day to day a few of the wasps became entirely reconciled to our interference, and paid no attention to the changes, while the others grew more or less accustomed to the idea of mutability, and were but little disturbed, although they still showed their consciousness of each alteration by making a few circles before going in. We once placed some dark red nasturtiums on light yellow paper near the nest, and found that more than one third of the homecoming wasps flew to them and hovered over them before entering. When light yellow nasturtiums, nearly matching the paper in color, were substituted, only one out of thirty-six noticed them; and as the odor was as strong in one case as the other, it would seem that the color was the attracting force.

Our final color experiment was to let the blue paper remain for a day or two, giving time for all the wasps to become familiar with it, and then to leave it on the ground a foot and a half away, while replacing it with yellow. This gave a false nest surrounded by the color that they had been associating with the entrance, and a true nest surrounded by a new color. In the next ten minutes two hundred and seventy wasps came home, and every one of them went to the false nest. Many circled above it, others entered the hole in the paper, and some began to excavate, and made quite a depression in the ground; but gradually they found their way home. Three hours later seventy-six wasps entered the false nest in five minutes, and at evening they were still visiting it in goodly numbers; but on the next day we saw only two that were deceived.

On successive days we substituted red for yellow, green for red, and so on, always with similar results, although the wasps became more and more accustomed to the vicissitudes of their life, and after a time seemed to look for the hole itself without relying upon the color to guide them. They found their nest under a color new to them much more readily than when the paper was taken entirely away and the ground left exposed. Once when the green paper was around their nest, and the wind

blew it over the hole so that they could not enter, at least one hundred collected, many of them settling in the false nest; when we lifted the green paper, leaving the hole free, only three or four entered, but when we put it back in place they rushed in six or seven at a time. It was plainly the color that directed them.

This was a nearly rainless summer, — a condition extremely favorable to wasp development. Nests multiplied and grew until the whole country-side complained, and no wonder, for houses were full of them, and at meal-times they gathered at the table with the members of the family. How did they know when dinner was ready? It could not have been by the sight, unfamiliar to them, of cooked food; was it, then, through the sense of smell?

Many were the questions that we asked in vain of our Vespas, but here was one that they could readily be made to answer. We rolled up two bundles, one of nothing but gauze, and another, like it in appearance, but containing some warm chicken bones; these were laid to one side of the nest, the color of the gauze matching that of the paper on which it was placed. The wasps in returning to the nest, even though loaded with food, could not resist the appetizing odor, and settled thickly upon the bone bundle, trying their best

to penetrate within, while the empty gauze was unnoticed. As the bones grew cold and dry they attracted less attention, but two days later they were occasionally visited.

Having killed two wasps that had alighted on the ground, by striking them with a folded paper, we took them up and placed one of them at a distance, so that it was entirely hidden in the grass. Five settled above it, and after they had carried it away the place was visited by several others, while the spot upon which we had killed them drew to it nine wasps within fifteen minutes. Thus they seemed very keen of scent where animal matter was concerned; but the powerful oils of peppermint and wintergreen, although noticed, aroused little attention, perhaps because they indicated nothing of interest to them.

Our experiments on hearing met with negative results. The wasps seemed insensible to any noise we could make or that we could produce by whistles of various degrees of shrillness. This of course does not show that they cannot hear, and any one who has been unfortunate enough to disturb them in the neighborhood of their nest will remember how their angry buzzing seemed to serve as a battle cry to gather all the members of the clan for the attack.

Our Vespas began to work an hour or two after sunrise, and did not stop until dusk. One cloudy evening when darkness fell early they continued to return to the nest, being able to fly to the right spot without any hesitation, although our vision did not permit us to see the opening without going down on our knees and looking closely. At last it grew perfectly dark, and we stuffed a handkerchief into the hole, with the result that seventy-five, coming home without a ray of light to guide them, were shut out, and were found clustered about the spot on the following morning.

We wanted to estimate the amount of labor done by a worker in a day, and so, rising one morning at the first bird call, we went out into the freshness of dawn, and for an hour had the world to ourselves; but a little before five a few straggling wasps that had stayed out all night began to bring in loads, and by half past seven they were fairly under way. From half past four until twelve we counted all that passed, 4534 going out and 3362 coming home; and with all this activity there seemed to be no pleasure excursions, for each one carried food when returning, and took out a pellet of earth when leaving. We once raised a little garden from the pellets that were dropped on our porch table where we kept a bowl of water. Wasps are great drinkers, and when they find

such a provision they come frequently to refresh themselves, dropping their loads as they alight. This habit of holding on to their loads until they settle down may perhaps make them a factor in extending the boundaries of plant distribution, both under ordinary conditions and when, as must often happen with little creatures flying so high, they are blown to long distances from home.

Having kept close track not only of the numbers, but of the hours, each count being made to cover five minutes, we were able to calculate that an average trip occupied forty-three minutes. When we met these wasps in the garden they never seemed to be hurrying, and had the air of amusing themselves; but they must be faithful workers to accomplish so much. The curious fact has been established that when food is very plentiful the workers

PAPER NEST WITH SIDE REMOVED TO SHOW CONSTRUCTION OF COMBS

begin to lay male eggs, thus taking from the queen a part of her burden and leaving her free to produce neuters and females. The nest that we were watching was found, at the end of the season, to contain 4661 wasps in various stages of development, and others that we opened had from two to four thousand. This is nothing to the social wasps of China, where a single household is made up of from fifteen to twenty thousand members; but China is a thickly populated country, and perhaps with wasps as with human beings several families live in a single domicile.

Outside of their wonderful social instincts our wasps are found wanting in the higher gifts of emotion and intellect. When we killed a number of them and placed them near the nest, their nearest relatives wasted no time in mourning, nor yet in revenge, but calmly cut up the bodies and fed them to the ever hungry young ones. If we placed some rich and tempting morsels at a distance, two or three would discover them, and would go back and forth all day without telling the others about it, as ants would have done under like circumstances. When we obstructed the opening to their nest by lightly laying blades of grass across, the day passed without its occurring to the wasps to lift them away, although they suffered the greatest inconvenience in getting in and out,

crawling laboriously through, and in some instances giving up the task and flying away.

Vespa maculata, building on trees and fences, has practically the same habits as the ground wasp, germanica, the internal structure of the nest following the same plan, while the outer wall is of a papery substance like that of the combs, made from the scrapings of weather-beaten wood. The genus Polistes builds combs similar to that of Vespa, under porches or in any sheltered place, and does not inclose them. All these wasps, when adult, enjoy fruit and flowers as well as animal food; but only this last is used for the young, and many a caterpillar creeping along with sinister design is snatched by them to be chewed into a pulpy mass, and then fed to the larvæ. No calculation has been made of the value of these wasps in agriculture, and one of the things that farmers have yet to learn is to encourage their presence in orchards and gardens.

Some species are said to sting the drones and larvæ to death at the close of the season, but this habit is not followed by V. germanica and V. maculata. Since there is no store of provision to be economized through the winter the only object of such conduct would be the merciful one of ending their sufferings at once instead of letting them perish by slow starvation, and we find no evidence

for such elevated ideas. What makes for the welfare of the species they thoroughly attend to, but beyond that point they do not go.

The socialism of wasps is in a less evolved state than that of bees and ants, and yet there is in it sufficient sacrifice of self to the common good to excite the respectful wonder of human beings, whose relations to each other and to the state have such different standards.

Chapter II

AMMOPHILA AND HER CATERPILLARS

BEFORE we had worked long on our Vespa family we were beguiled by tempting opportunities into running after the solitary wasps. The solitaries, so far as species are concerned, are immensely more numerous than the socials ; but they have only two sexes, and the males and females usually see but little of each other after the mating is over, although we occasionally find them living happily together until the end of the season. In the early summer they begin to emerge from the nest in which the eggs were laid the year before. Solitary indeed they come into the world, the generation that gave them birth having perished in the fall. For a time their career is one of unmixed pleasure, and yet, free and unguided though they are, basking in the sunshine, feeding on the flowers, or sleeping at night under some sheltering leaf, they are hourly acquiring experience, so that when the cares of life descend upon them they are no longer creatures of mere instinct. With these sobering cares an

almost absurdly heavy sense of responsibility for future generations transforms the hitherto happy-go-lucky females into grown-up wasps with serious views on marketing and infant foods. Each one makes a separate nest and provisions it by her own labor ; and in many cases a new nest is made for each egg. There is no coöperation among them ; although in certain genera, as Aphilanthops and Bembex, a number of individuals build close together, forming a colony. The nests may be made of mud, and attached for shelter under leaves, rocks, or eaves of buildings, or may be burrows hollowed out in the ground, in trees or in the stems of plants. The adult wasp lives upon fruit or nectar, but the young grub or larva must have animal food; and here the parent wasp shows a rigid conservatism, each species providing the sort of food that has been approved by its family for generations, one taking flies, another bugs, and another beetles, caterpillars, grasshoppers, crickets, locusts, spiders, cockroaches, aphides, or other creatures, as the case may be.

When the egg-laying time arrives the female secures her prey, which she either kills or paralyzes, places it in the nest, lays the egg upon it, and then, in most cases, closes the hole and takes no further interest in it, going on to make new nests from day to day. In some genera the

female maintains a longer connection with her offspring, not bringing all the provision at once, but returning to feed the larva as it grows, and leaving the nest permanently only when the grub has spun its cocoon. The males never acquire this interest, so admirable for the development of character, and aid little, if at all, in the care of the family. The egg develops in from one to three days into a footless, maggot-like creature which feeds upon the store provided for it, increasing rapidly in size, and entering the pupal stage in from three days to two weeks. In the cocoon it passes through its final metamorphosis, emerging as a perfect insect, perhaps in two or three weeks, or, in many cases, after the winter months have passed and summer has come again.

Most graceful and attractive of all the wasps — "*taille effilée, tournure svelte,*" as Fabre describes them, the Ammophiles, of all the inhabitants of the garden, hold the first place in our affections. Not so beautiful as the blue Pelopæus, nor so industrious as the little red-girdled Trypoxylon, their intelligence, their distinct individuality, and their obliging tolerance of our society make them an unfailing source of interest. They are, moreover, the most remarkable of all genera in their stinging habits, being supposed to use the nicest surgical skill in paralyzing their caterpillars; and few things have given us

deeper pleasure than our success in following the activities and penetrating the secrets of their lives. In our garden we have two species of Ammophila, urnaria Cresson, and gracilis Cresson, both of them being very slender-bodied wasps of about an inch in length, gracilis all black, and urnaria with a red band around the front end of the abdomen. A. polita and A. vulgaris, which look much like urnaria, are common in the sandy fields west and south of Milwaukee.

During the earlier part of the summer we had often seen these wasps feeding upon the nectar of flowers, especially upon that of the sorrel, of which they are particularly fond; but at that time we gave them but passing notice. One bright morning, however, we came upon an urnaria that was so evidently hunting, and hunting in earnest, that we gave up everything else to follow her. The ground was covered, more or less thickly, with patches of purslain, and it was under these weeds that our Ammophila was eagerly searching for her prey. After thoroughly investigating one plant she would pass to another, running three or four steps and then bounding as though she were made of thistledown and were too light to remain upon the ground. We followed her easily, and as she was in full view nearly all of the time we had every hope of witnessing the capture; but in this we were des-

tined to disappointment. We had been in attendance on her for about a quarter of an hour when, after disappearing for a few moments under the thick purslain leaves, she came out with a green caterpillar. We had missed the wonderful sight of the paralyzer at work; but we had no time to bemoan our loss, for she was making off at so

AMMOPHILA URNARIA CARRYING CATERPILLAR TO NEST

rapid a pace that we were well occupied in keeping up with her. She hurried along with the same motion as before, unembarrassed by the weight of her victim. For sixty feet she kept to open ground, passing between two rows of bushes; but at the end of this division of the garden, she plunged, very much to our dismay, into a field

of standing corn. Here we had great difficulty in following her, since, far from keeping to her former orderly course, she zigzagged among the plants in the most bewildering fashion, although keeping a general direction of northeast. It seemed quite impossible that she could know where she was going. The corn rose to a height of six feet all around us; the ground was uniform in appearance, and, to our eyes, each group of cornstalks was just like every other group, and yet, without pause or hesitation, the little creature passed quickly along, as we might through the familiar streets of our native town.

At last she paused and laid her burden down. Ah! the power that has led her is not a blind, mechanically perfect instinct, for she has traveled a little too far. She must go back one row into the open space that she has already crossed, although not just at this point. Nothing like a nest is visible to us; the surface of the ground looks all alike, and it is with exclamations of wonder that we see our little guide lift two pellets of earth which have served as a covering to a small opening running down into the ground.

The way being thus prepared, she hurries back with her wings quivering and her whole manner betokening joyful triumph at the completion of her task. We, in the mean time, have become as much excited over the

matter as she is herself. She picks up the caterpillar, brings it to the mouth of the burrow, and lays it down. Then, backing in herself, she catches it in her mandibles and drags it out of sight, leaving us full of admiration and delight.

How clear and accurate must be the observing powers of these wonderful little creatures! Every patch of ground must, for them, have its own character; a pebble here, a larger stone there, a trifling tuft of grass — these must be their landmarks. And the wonder of it is that their interest in each nest is so temporary. A burrow is dug, provisioned and closed up, all in two or three days, and then another is made in a new place with everything to learn over again.

From this time on to the first of September our garden was full of these wasps, and they never lost their fascination for us; although, owing to a decided difference between their taste and ours as to what constituted pleasant weather, all our knowledge of them was gained by the sweat of our brows. When we wished to utilize the cool hours of the morning or of the late afternoon in studying them, or thought to take advantage of a cloud which cast a grateful shade over the sun at noonday, where were our Ammophiles? Out of sight entirely, or at best only to be seen idling about on the flowers of the onion or

sorrel. At such a time they seemed to have no mission in life and no idea of duty. But when the air was clear and bright and the mercury rose higher and higher, all was changed. Their favorite working hours were from eleven in the morning to three in the afternoon, and when they did work they threw their whole souls into it. It was well that it was so, for they certainly needed all the enthusiasm and perseverance that they could muster for such wearisome and disappointing labor. Hour after hour was passed in search, and often there was nothing to show at the end of it. Urnaria hunted on bare ground, on the purslain, and most of all on the bean-plants. These were examined carefully, the wasp going up and down the stems and looking under every leaf; but the search was so frequently unsuccessful that in estimating their work we are inclined to think that they can scarcely average one caterpillar a day.

In this species, as in every one that we have studied, we have found a most interesting variation among the different individuals, not only in methods, but in character and intellect. While one was beguiled from her hunting by every sorrel blossom she passed, another stuck to her work with indefatigable perseverance. While one stung her caterpillar so carelessly and made her nest in so shiftless a way that her young could survive only

through some lucky chance, another devoted herself to these duties not only with conscientious thoroughness, but with an apparent craving after artistic perfection that was touching to see.

The method employed by the Ammophiles in stinging their prey is more complex than that of any other predatory wasp. The larvæ with which they provision their nests are made up of thirteen segments, and each of these has its own nervous centre or ganglion. Hence if the caterpillar is to be reduced to a state of immobility, or to a state so nearly approaching immobility that the egg may be safely laid upon it, a single sting, such as is given by some of the Pompilidæ to their captured spiders, will be scarcely sufficient. All this we knew from Fabre's "Souvenirs," and yet we were not at all prepared to believe that any plain American wasp could supply us with such a thrilling performance as that of the Gallic hirsuta, which he so dramatically describes. We were, however, most anxious to be present at the all-important moment that we might see for ourselves just how and where urnaria stings her victim.

For a whole week of scorching summer weather we lived in the bean patch, scorning fatigue. We quoted to each other the example of Fabre's daughter Claire, who followed Odynerus with unfaltering zeal until a sun-

stroke laid her low. We attended scores of wasps as they hunted; we ran, we threw ourselves upon the ground, we scrambled along on our hands and knees in our desperate endeavors to keep them in view, sometimes with our eyes upon the wasps themselves and sometimes pursuing their shadows, which, like those of coming events, were cast before; and yet they escaped us. After we had kept one in sight for an hour or more, some sudden flight would carry her far away, and all our labor was lost.

At last, however, our day came. We were doing a little hunting on our own account, hoping to find some larvæ which we could drop in view of the wasps and thus lead them to display their powers, when we saw an urnaria fly up from the ground to the underside of a bean leaf and knock down a small green caterpillar. Breathless with an excitement which will be understood by those who have tasted the joy of such a moment, we hung over the actors in our little drama. The ground was bare, we were close by and could see every motion distinctly. Nothing more perfect could have been desired.

The wasp attacked at once, but was rudely repulsed, the caterpillar rolling and unrolling itself rapidly and with the most violent contortions of the whole body. Again and again its adversary descended, but failed to

gain a hold. The caterpillar, in its struggles, flung itself here and there over the ground, and had there been any grass or other covering near by it might have reached a place of partial safety; but there was no shelter within reach, and at the fifth attack the wasp succeeded in alighting over it, near the anterior end, and in grasping its body firmly in her mandibles. Standing high on her long legs and disregarding the continued struggles of her victim, she lifted it from the ground, curved the end of her abdomen under its body, and darted her sting between the third and fourth segments. From this instant there was a complete cessation of movement on the part of the unfortunate caterpillar. Limp and helpless, it could offer no further opposition to the will of its conqueror. For some moments the wasp remained motionless, and then, withdrawing her sting, she plunged it successively between the third and the second, and between the second and the first segments.

The caterpillar was now left lying on the ground. For a moment the wasp circled above it, and then, descending, seized it again, further back this time, and with great deliberation and nicety of action gave it four more stings, beginning between the ninth and tenth segments and progressing backward.

Urnaria, probably feeling — as we certainly did — a

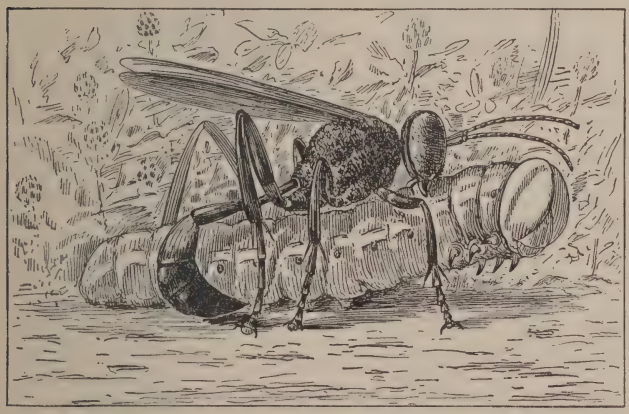
reaction from the strain of the last few minutes, and a relief at the completion of her task, now rested from her labors. Alighting on the ground close by, she proceeded to smooth her body with her long hind legs, standing, in the mean time, almost on her head, with her abdomen directed upward. She then gave her face a thorough washing and rubbing with her first legs, and not until she had made a complete and satisfactory toilet did she return to the caterpillar.

We saw Ammophila capture her prey only three times during the whole summer; but from these observations and from the condition of her caterpillars taken at various times from nests, her method seems to be wonderfully close to that of hirsuta, with just about the same amount of variation in different individuals.

Thus in our second example, she stung the first three segments in the regular order, the third, the second, and lastly (and most persistently) the first. She then went on, without a pause, to sting the fourth, fifth, sixth, and seventh, stopping at this point and leaving the posterior segments untouched. In our first example, it will be remembered, the middle segments were spared. The stinging being completed, she proceeded to the process known as *malaxation*, which consists in repeatedly squeezing the neck of the caterpillar, or other victim,

between the mandibles, the subject of the treatment being turned around and around so that all sides may be equally affected.

In our third case a caterpillar which we had caught was placed in front of a wasp just after she had carried the second larva into her nest. She seemed rather indifferent to it, passing it once or twice as she ran about, but finally picked it up and gave it one prolonged sting between the third and fourth segments. She then spent a



AMMOPHILA URNARIA STINGING CATERPILLAR

long time in squeezing the neck, pinching it again and again, after which it was left on the ground; and as she showed no further interest in it we carried it home for further study.

In the three captures, then, that came under our observation, all the caterpillars being of the same species and almost exactly of the same size, three different methods were employed. In the first, seven stings were given at the extremities, the middle segments being left untouched, and no malaxation was practiced. In the second, seven stings again, but given in the anterior and middle segments, followed by slight malaxation. In the third, only one sting was given, but the malaxation was prolonged and severe.

Let us now compare these variations with those of Fabre. In his first case the sting entered at twelve different points, beginning between the first and second segments and progressing regularly backward. There was no malaxation. In his second example the third, second, and first segments were stung in the order given, and thereafter each succeeding segment up to the ninth, nine stings being given in all, with careful malaxation following. In his later experiments, which seem to have been numerous, he found that as a usual thing all the segments were stung, although the posterior three or four were occasionally spared, but that the order in which they were operated upon, as well as the amount of malaxation, was very variable.

Our conclusions, then, as to Ammophila's methods of

stinging agree fairly well with those of Fabre; but there is one important exception. In his cases the middle segments, upon one of which the egg is laid in our species as well as in his, were invariably stung, and this he considers a point of extreme importance. In one of our cases the middle segments were not touched.

CATERPILLAR WITH EGG OF AMMOPHILA URNARIA

The point in which our observations differ most widely from those of Fabre is in the condition of the caterpillars after the stinging. He seems to have found that they always lived a long time, but in a motionless or nearly motionless state; and he dwells at length upon the necessity of both of these conditions, since he believes that while the wasp larva must have perfectly fresh food, any violent motion would imperil its safety. As a matter of fact we found a wide variation in the thoroughness with which the wasps performed their task. We had, in all, fifteen caterpillars upon which urnaria had worked her will; and while a few of them fulfilled to a nicety the conditions which Fabre believes to be imperative, most of them were far from doing so. Some of them lived only three days, others a little longer, while still others showed

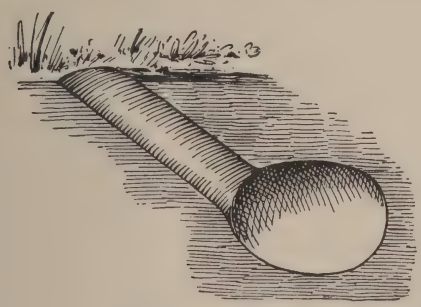
signs of life at the end of two weeks. Urnaria stores two caterpillars, and in more than one instance the second one died and became discolored before the first one was entirely eaten. The wasp larva did not, as might have been expected, find fault with this arrangement, but proceeded to attack number two with good appetite, ate it all up, and then spun its cocoon as though nothing unpleasant had occurred.

The second condition was also violated. In one case the bite of the newly hatched larva caused the caterpillar to rear upon end in so violent a manner that it looked as though the little creature would surely be dislodged. Another caterpillar kept up a continuous wriggling without any external stimulation, and when it was touched it rolled about almost as these larvæ do in a healthy state, and yet the egg was not shaken off. The caterpillar which received but a single sting, although not motionless, would have been a safer repository for the egg than either of these. Others fulfilled Fabre's condition perfectly, lying immovable except when stimulated, and then responding only by a slight quivering of the legs or skin.

Among the fifteen caterpillars that we have taken from the nests of urnaria three kinds are represented, twelve of them belonging to one species, two to the second, and one to the third.

The egg, which is laid upon the side of the sixth or seventh segment, hatches in from two to three days; the larva spends from six days to two weeks in eating, and then spins its pale yellowish cocoon.

The nesting habits of urnaria closely resemble those of the other members of the genus, as reported by various observers. The spot chosen is in firm soil, sometimes in open ground, but much more frequently under the leaves of some plant. The plan is a very simple one.



NEST OF AMMOPHILA

A tunnel of about an inch in length leads to the pocket in which the caterpillars are stored. There is no hardening of the walls in any part. We took pains to draw every nest that we opened, and there was a very considerable variation in the minor details, such as the obliquity of the entrance tunnel, the shape of the pocket,

and the angle at which the tunnel and pocket were joined.

The work is done with the mandibles and the first legs. When it has proceeded so far that the wasp is partly hidden, she begins to carry the earth away from the nest. In doing this she backs up to the edge of the opening and, flying a little way, gives a sort of flirt which throws the pellet that she carries in her mandibles to a distance. She then alights where she is and pauses a moment before she runs back to the hole, or, in some cases, darts back on the wing. We watched the process of nest-making five times during the summer. In the first instance Ammophila, having made her excavation, ran off and after some search returned with a good-sized lump of earth. This she laid over the opening, which was now entirely hidden. She then flew to the bean patch close by, but after ten minutes she came back and looked at her nest. It was so neatly covered as to be almost indistinguishable, but to this fastidious little creature something seemed lacking. She pulled away the cover, carried out three or four more loads, and then began to search for another piece for closing. After a time she came hurrying back with a lump of earth, but when close to the nest she concluded that it would not do, dropped it, and ran off in another direction. Presently

she found one which fitted into the hole exactly, and after placing it she brought a much smaller piece which she put above and to one side. She then stood back and surveyed the whole, and it seemed to us that we could read pride and satisfaction in her mien. She then flew away, and we supposed that that stage of the work was completed. Upon coming back two hours later, however, we found that she had been trying some more improvements, as a number of little pellets had been piled up over the nest. This wasp, by the way, never succeeded in finding a caterpillar, since when we opened the burrow a few days later it was still empty. Perhaps she came to some untimely end.

Of the other wasps that we saw making a temporary closure of their nests, one wedged a good-sized stone deep down into the neck of the burrow and then filled the space above, solidly, with smaller stones and earth. Another placed two lumps of earth just below the surface of the ground, filled the opening with pellets loosely thrown in, and then kicked some light dust over the whole. The others used only two or three lumps of earth, which they fitted neatly into the opening just below the surface. Although it is usual for urnaria to leave her nest closed while she is off searching for her prey, there is no invariable rule in the matter, even for single individ-

uals. Once having seen a wasp dig her nest and close it up, we drew some radiating lines from the spot, in the light dust that covered the place, that we might find it again. When we returned, two hours later, the same wasp had made a nest four or five inches distant from the first one, and had left it wide open, while she had gone off to search for her caterpillar. She had probably been alarmed by the marks that we had made, and had felt it necessary to dig a new nest, but being in a hurry to lay her egg had omitted the usual process of closing it. We witnessed the storing of the caterpillar and the final closing.

From Fabre we learn that argentata and sabulosa close the nest as soon as it has been made, at least when the provisioning is to be postponed until the next day, while holosericea leaves it open until it is completely stored. He suggests an explanation for this variation by dwelling upon the inconvenience that would result if it were opened every time that the wasp brought in a caterpillar, since holosericea stores up five or six small larvæ instead of one or two large ones. But what, then, shall be said of polita and yarrowii, which, while they also store a number of small caterpillars, take pains to close and conceal the entrance every time they come out? We see the same habit in other genera where the

mother continually passes in and out, as in Bembex and Oxybelus.

Fabre thinks that hirsuta has the habit, unusual for Ammophila, of catching her prey first and then digging the hole in which she bestows it. As she takes only one large caterpillar she is thus relieved of the necessity of closing the nest more than once.

As has been said, urnaria usually hunts a long time before she finds her caterpillar, and one or two days may pass before anything is put into the nest. During this prolonged search she often revisits the spot, and thus keeps fresh the memory of its locality. As soon as the first caterpillar is stored she lays an egg on it, and then closes the nest as before. The second one may be brought in within a few hours; but in one instance that came under our notice we feel sure that the interval was as much as three days. We saw the interment of the second caterpillar, and upon excavating, found on the first one a larva at least a day old; we suppose that at least two days had elapsed between the laying and the hatching of the egg.

When the provisioning is completed the time arrives for the final closing of the nest; and in this, as in all the processes of Ammophila, the character of the work differs with the individual. For example, of two wasps that

we saw close their nests on the same day, one wedged two or three pellets into the top of the hole, kicked in a little dust, and then smoothed the surface over, finishing it all within five minutes. This one seemed possessed by a spirit of hurry and bustle, and did not believe in spending time on non-essentials. The other, on the contrary, was an artist, an idealist. She worked for an hour, first filling the neck of the burrow with fine earth which was jammed down with much energy, — this part of the work being accompanied by a loud and cheerful humming, — and next arranging the surface of the ground with scrupulous care, and sweeping every particle of dust to a distance. Even then she was not satisfied, but went scampering around, hunting for some fitting object to crown the whole. First she tried to drag a withered leaf to the spot, but the long stem stuck in the ground and embarrassed her. Relinquishing this, she ran along a branch of the plant under which she was working and, leaning over, picked up from the ground below a good-sized stone; but the effort was too much for her, and she turned a somersault on to the ground. She then started to bring a large lump of earth; but this evidently did not come up to her ideal, for she dropped it after a moment, and seizing another dry leaf carried it successfully to the spot and placed it directly over the nest. A third

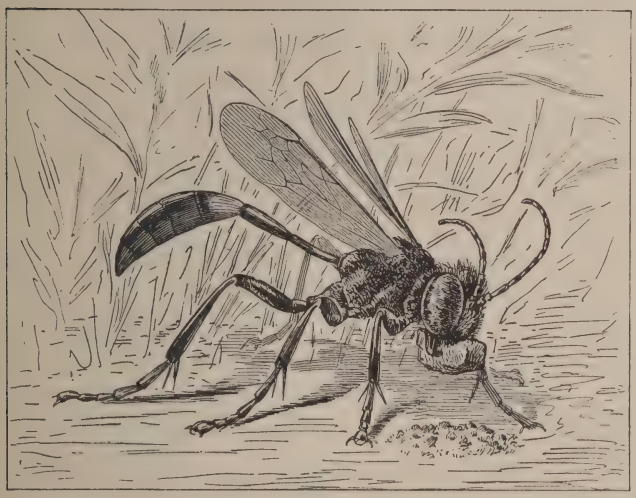
instance of the final closing of the nest was intermediate between these two, the work occupying twenty minutes. The wasp first put a plug well down, then dropped in several large pellets, brushed in a quantity of fine earth, and finally smoothed the surface over.

We had another much less worthy example, one, indeed, that went to the extreme of carelessness. We first saw her in the morning carrying her caterpillar across the field. She frequently dropped it and ran or flew to a little distance, and when she took it again the venter was sometimes up and sometimes down, whichever way it happened. Her nest was a very poor affair just beneath the surface, and after the caterpillar was carried in, it was visible from above. She filled the hole with loose particles of earth and then scratched the surface of the ground a little in a perfunctory sort of way, as different as possible from the painstaking labor that we had been accustomed to in her sisters. That afternoon we opened the nest and removed its contents. The next morning we saw this wasp bringing home her second caterpillar. She was much puzzled and disturbed at the destruction of her nest, and hunted for it for an hour and a half, leaving the caterpillar on the ground near by. We could not help feeling sorry that we had interrupted the contented routine of her life. She finally gave

up in despair, and we took possession of the deserted caterpillar.

Just here must be told the story of one little wasp whose individuality stands out in our minds more distinctly than that of any of the others. We remember her as the most fastidious and perfect little worker of the whole season, so nice was she in her adaptation of means to ends, so busy and contented in her labor of love, and so pretty in her pride over the completed work. In filling up her nest she put her head down into it and bit away the loose earth from the sides, letting it fall to the bottom of the burrow, and then, after a quantity had accumulated, jammed it down with her head. Earth was then brought from the outside and pressed in, and then more was bitten from the sides. When, at last, the filling was level with the ground, she brought a quantity of fine grains of dirt to the spot, and picking up a small pebble in her mandibles, used as it a hammer in pounding them down with rapid strokes, thus making this spot as hard and firm as the surrounding surface. Before we could recover from our astonishment at this performance she had dropped her stone and was bringing more earth. We then threw ourselves down on the ground that not a motion might be lost, and in a moment we saw her pick up the pebble and again pound

the earth into place with it, hammering now here and now there until all was level. Once more the whole process was repeated, and then the little creature, all unconscious of the commotion that she had aroused in



AMMOPHILA URNARIA USING STONE TO POUND DOWN EARTH OVER NEST

our minds, — unconscious, indeed, of our very existence and intent only on doing her work and doing it well, — gave one final, comprehensive glance around and flew away.

We are claiming a great deal for Ammophila when we say that she improvised a tool and made intelligent use

of it, for such actions are rare even among the higher animals; but fortunately our observation does not stand alone, although we supposed this to be the case at the time that it was made. Some weeks later, seeing a note of a similar occurrence by Dr. S. W. Williston, of Kansas University, we wrote to him on the subject. In his reply he said that he had waited for a year before venturing to publish his observation, fearing that so remarkable a statement would not be credited. His account is so interesting that we quote it at length.

Even the casual observer, to whom all insects are bugs, cannot help but be struck by the great diversity and number of the fossorial Hymenoptera of the plains. Water is often inaccessible, trees there are few or none, and only in places is the vegetation at all abundant. A much larger proportion of insects, hence, find it necessary to live or breed in holes in the ground, than is the case in more favored localities. Especially is this the case with the Hymenoptera, great numbers and many species of which thus breed in excavations made by themselves.

While packing specimens on an open space, uncovered by buffalo grass, in the extreme western part of Kansas, the early part of last July, the attention of a friend and myself was attracted by the numerous wasps that were constantly alighting upon the ground. The hard, smooth baked surface showed no indications of disturbance, and it was not till we had attentively watched the insects that

we learned what they were doing. The wasp is a very slender one, more than an inch in length, with a slender, pedicellate abdomen; it is known to entomologists as Ammophila yarrowii Cres. They were so numerous that one was distracted by their very multiplicity, but, by singling out different individuals, we were enabled to verify each detail of their operations. An insect, alighting, ran about on the smooth, hard surface till it had found a suitable spot to begin its excavation, which was made about a quarter of an inch in diameter, nearly vertical, and carried to a depth of about four inches, as was shown by opening a number of them. The earth, as removed, was formed into a rounded pellet and carefully carried to the neighboring grass and dropped. For the first half of an inch or so the hole was made of a slightly greater diameter. When the excavation had been carried to the required depth, the wasp, after a survey of the premises, flying away, soon returned with a large pebble in its mandibles, which it carefully deposited within the opening; then, standing over the entrance upon her four posterior feet, she (I say she, for it was evident that they were all females) rapidly and most amusingly scraped the dust with her two front feet, "hand over hand," back beneath her, till she had filled the hole above the stone to the top. The operation so far was remarkable enough, but the next procedure was more so. When she had heaped up the dirt to her satisfaction, she again flew away and immediately returned with a smaller pebble, perhaps an eighth of an inch in diameter, and then standing more nearly erect, with the

front feet folded beneath her, she pressed down the dust all over and about the opening, smoothing off the surface, and accompanying the action with a peculiar rasping sound. After all this was done, and she spent several minutes each time in thus stamping the earth so that only a keen eye could detect any abrasion of the surface, she laid aside the little pebble and flew away to be gone some minutes. Soon, however, she comes back with a heavy flight, scarcely able to sustain the soft green larva, as long as herself, that she brings. The larva is laid upon the ground, a little to one side, when, going to the spot where she had industriously labored, by a few, rapid strokes she throws out the dust and withdraws the stone cover, laying it aside. Next, the larva is dragged down the hole, where the wasp remains for a few minutes, afterwards returning and closing up the entrance precisely as before. This, we thought, was the end, and supposed that the wasp would now be off about her other affairs, but not so; soon she returns with another larva, precisely like the first, and the whole operation is again repeated. And not only the second time, but again and again, till four or five of the larvæ have been stored up for the sustainment of her future offspring. Once, while a wasp had gone down the hole with a larva, my friend quietly removed the door stone that she had placed by the entrance. Returning, she looked about for her door, but not finding it, apparently mistrusted the honesty of a neighbor, which had just descended, leaving her own door temptingly near. She purloined this pebble and was making off with it, when the rightful

owner appeared and gave chase, compelling her to relinquish it.

The things that struck us as most remarkable were the unerring judgment in the selection of a pebble of precisely the right size to fit the entrance, and the use of the small pebble in smoothing down and packing the soil over the opening, together with the instinct that taught them to remove every evidence that the earth had been disturbed.

Since the Ammophiles of our species make their nests first and then do their hunting it follows that they must sometimes carry their prey for a considerable distance. The most ambitious attempt of this kind that we ever witnessed was made by gracilis.

The wasp was first seen carrying a large green caterpillar, which projected at both ends beyond her own body, across the potato field at the lower end of the garden. We could not tell how far she had already brought it, but judging by the direction from which she was coming, and by the fact that we had never seen that species of caterpillar in the garden, she had probably come through the fence from the woods beyond. She moved along briskly over the remaining part of the potato field, and then through an adjoining bean patch into the corn field. This had been a place of much anxiety to us earlier in the summer; but now the corn had

been stacked and we could follow her without difficulty. So far she had been going due south; but now she made a turn and plunged into the long, tangled grass which grew around and among some large, overgrown raspberry bushes. To keep track of her here seemed a hopeless task, but we resolved to do our best, and followed anxiously after. The wasp worked her way along about two inches above the ground and very much below the top of the grass, clinging to the blades with her feet and making surprisingly good progress. When half way through the raspberry bushes she carried the caterpillar up on to a branch, deposited it there, and after circling about to take her bearings, flew away, doubtless to visit her nest and to make sure that she was going in the right direction.

We, ourselves, were very glad of the chance to rest our tired eyes and nerves from the strain of following her. The journey, so far, had occupied nearly an hour, at almost every instant of which it had been exceedingly difficult to keep her in view. But for our united efforts we should certainly have failed.

While standing guard over the caterpillar we noticed that it moved its head from side to side, showing that the first segment could not have been severely stung, as is usually the case in the work of urnaria.

In five minutes the wasp returned, and, with the air of feeling that everything was right, picked up her burden and carried it laboriously through the remaining bushes and then through the grassy space that edged the garden, as far as the rail fence which separated this part of the grounds from the woods. Without a pause she climbed on to this fence to the height of the second rail, passed through, and flew down on the further side. Here she paused a moment, perhaps to take breath, and we looked at each other in some dismay. Whither was she leading us? We had now been following her for over an hour, and she looked equal to as much again as she started off once more, rapidly this time, for the grass was short here and the traveling was easy. Soon, however, it became evident that things were going wrong, although we could not determine what was the matter. The caterpillar was laid down while the wasp absented herself for six minutes. She returned and carried it for fifteen minutes, and then left it for half an hour. Once more she came back, and carried it for ten minutes, and then she flew away. It was now four o'clock, and we had been following her since two. We watched over the caterpillar for an hour longer, but saw no more of the wasp.

Did she become discouraged at the magnitude of her task? It would have been a thousand times easier for

her to have dug her nest close by the place of capture, but perhaps she had one larva already stored with her egg upon it. The caterpillar was carried two hundred and sixty-one feet while we watched her, with an unknown distance at each end to complete the line between the place of capture and the nest. She could scarcely have lost her way, since at every return she proceeded on her journey in one general direction without any hesitation. It seems probable then that she had hunted too far afield, and did not realize, when she started with her booty, what an undertaking it would be to carry it to the nest. We once saw A. vulgaris have a similar experience. She was running along with a small green caterpillar, but became discouraged either at the difficulty of finding her nest, or at the distance she had to cover. She would carry the caterpillar a little way, drop it, circle about a while, and then pick it up again; but finally she gave up the whole undertaking and flew away.

The affairs of Ammophila must frequently go wrong, since in still another of our few examples we saw much trouble and labor wasted. The wasp, in this case an urnaria, captured her caterpillar successfully and proceeded to carry it off. She was far from being in a hurry, going along for a foot or so, and then making a long pause, during which she would lay it down and either

circle above it, perhaps to take bearings, or spend the time in cleaning herself off, stroking and smoothing every part of her body with the utmost care and deliberation. Her stops were so frequent and so lengthy that nearly an hour was occupied in going about twenty-five feet. When, at last, the nest was reached, the plug was removed from the entrance and the caterpillar dragged in, but almost immediately the wasp came out backwards with the point of an egg projecting from the extremity of her abdomen. She ran around and around the nest in a distracted way four or five times and then went back, dragged the caterpillar out, and carried it away. The egg came out further and further, and finally dropped on the ground and was lost. The wasp, carrying the caterpillar, led us a long dance, in a great semicircle over the field, coming back to the nest at last. Instead of going in, however, she was about to start off on another tour when we took her prey from her and placed it in the nest. The wasp remained in the neighborhood for over an hour, but finally disappeared. The nest was not closed, and when we dug it up on the following day it contained only the caterpillar that we had put in.

We could usually enter into the feelings of the Ammophiles and understand the meaning of their actions; but

we were puzzled once, when we saw an urnaria that had stored her second caterpillar and closed her nest permanently, spend the rest of her morning in hunting. Why in hunting? She had not dug a nest, she could not lay another egg at once, she did not want a caterpillar, for when we offered her one she stung it and then left it lying on the ground. The sun was bright, the sorrel-blossoms invited her. Surely it would have been the part of a rational wasp to have passed the rest of the day in feasting and fun.

We have said that urnaria stores two caterpillars, but this rule is not without its exception. It was on the last day of the summer that on a visit to our dear and fruitful potato field, we came upon a wasp of almost double the ordinary size, that made, when flying, a loud hum that at once attracted attention. She was just completing and closing her nest, and we determined to watch and see what kind of a victim she would bring in, as it seemed improbable that this great creature would content herself with the ordinary fare of the species. The opening to the nest measured half an inch in diameter.

It was eleven o'clock when she flew away. At half past twelve she reappeared, coming from the direction of the woods, opened her nest, and took out a few more pellets.

Then she flew to a bush which grew against the fence, three feet away, and following her quickly we saw an immense green caterpillar placed high up on a branch. It must have taken both strength and perseverance to lift this heavy weight so far from the ground. She seized it at once and carried it down, not flying, as these wasps sometimes do when they are descending with a burden, and then dragged it into her nest, where it fitted rather tightly. This nest was so shallow and so obliquely directed that the caterpillar was plainly visible after it had been taken in.

After she had laid her egg she crawled out, getting past the caterpillar with some difficulty, and closed the nest. There was certainly no room for any further store of provisions, and from the size of the caterpillar we judged that it would furnish sufficient nourishment even for the offspring of this wasp. We were, therefore, not surprised, upon opening the nest two days later, to find that nothing more had been brought. We have said that the wasp larvæ spend from six days to two weeks in eating. To be more exact, all that we watched, with the exception of the one which developed from the egg of this big creature, ate from six to eight days and then spun their cocoons; but this one seemed determined to reach the size of its mother, and ate continuously for

fourteen days. Of course long before this time had expired the remnant of the caterpillar had become a dry, dark-colored mass which looked little likely to tempt the appetite, but the great larva ate away with unabated relish, gradually acquiring the color and almost the thickness of the caterpillar it had destroyed.

Ammophila polita, which we have never seen in the country, is very common in the sandy fields to the south of Milwaukee. On the tenth of September, in bright clear weather, we found half a dozen individuals working within a few rods of each other, their method being similar to that of A. yarrowii, described by Dr. Williston, and having an especial interest, as it shows a transition stage between the wasps that provide the store of food all at once and those that feed their young all through the larval period. Urnaria rarely flies with her prey; but this wasp, although her caterpillars, are not very much smaller, and she herself is no larger, carries her booty lightly on the wing, alighting only occasionally to run a few steps. She has to do more work than urnaria, taking five or six caterpillars instead of two, and this method of progression has the advantage of rapidity.

The first wasp that we saw was just alighting with a medium-sized green caterpillar near a partly closed

nest. When disturbed she flew away, but soon returned, dropped her prey half an inch from the nest, proceeded to clear the opening, ran inside to see that all was right, and then backed in with the caterpillar. Emerging after a few minutes, she placed a small pebble in the doorway, which was thus partly closed, and flew away. She brought three more caterpillars at intervals of thirty minutes, and then, after wedging a pebble into the neck of the opening, she began to fill it in solidly, scratching in dirt and packing in lumps of earth which were brought in her mandibles. We did not allow her to complete this operation, as it would have made excavation more difficult, but caught her and dug out the nest. The tunnel ran down obliquely for five inches, being two inches below the surface at the pocket. In it we found a wasp larva, which was at least three days old, and four caterpillars. There were no signs of the banqueting which must have already taken place. We carried this larva home with us, and it ate the caterpillars up clean, finishing with a fifth which we supplied from another nest, and going into its cocoon on September sixteenth. The caterpillars all wriggled about on the slightest stimulation, and remained in this lively state until they were eaten. They belonged to four different species.

In a second nest to which food was being carried, we found four caterpillars and a larva about three days old, all the conditions being like those in the other example. Evidently the larva had been fed from day to day, since four or five days must have elapsed since the making of the nest.

Westwood states that Ammophila, when she has captured her prey, walks backward, dragging it after her;[1] but in all the cases that came under our notice she went forward, the caterpillar being grasped near the anterior end, in her mandibles, and either lifted above the ground or allowed to drag a little if long and heavy. It is usually held venter up, but in one case, in which the wasp, while carrying it to her nest, frequently laid it down and picked it up again, it was held with the venter down or up indifferently.

The all-important lesson that Fabre draws from his study of the Ammophiles is that they are inspired by automatically perfect instincts, which can never have varied to any appreciable extent from the beginning of time. He argues that deviation from the regular rule would mean extinction. For example, if the wasp should sting ever so little to one side of the median line the prey would be imperfectly paralyzed and the egg would

[1] *Introduction to Modern Classification of Insects*, ii, 189.

consequently be destroyed; or a sting in the wrong place might cause the death of the caterpillar and thus the death of the wasp larva, which, he thinks, can be nourished only by perfectly fresh food.

The conclusions that we draw from the study of this genus differ from these in the most striking manner. The one preëminent, unmistakable, and ever present fact is variability. Variability in every particular, — in the shape of the nest and the manner of digging it, in the condition of the nest (whether closed or open) when left temporarily, in the method of stinging the prey, in the degree of malaxation, in the manner of carrying the victim, in the way of closing the nest, and last, and most important of all, in the condition produced in the victims of the stinging, some of them dying and becoming "veritable cadavers," to use an expressive term of Fabre's, long before the larva is ready to begin on them, while others live long past the time at which they would have been attacked and destroyed if we had not interfered with the natural course of events. And all this variability we get from a study of nine wasps and fifteen caterpillars!

In his chapter on "Méthode des Ammophiles" Fabre says that each species has its own tactics, allowing no novitiate. "Not one could have left descendants if it

were not the handy workman of to-day. Any little slip is impracticable when the future of the race depends upon it." And yet we find that the prey may be stung so slightly that it can rear and wriggle violently or so severely that it dies almost at once, and in neither case is a break made in the generations of the Ammophiles, since in the former the egg or larva is so firmly fastened as to keep its hold, while in the latter the dead and decomposing caterpillar is eaten without dissatisfaction or injury.

Nor do we, in gathering evidence for the evolution of the instincts of these wasps, need to rely entirely upon our own observations. Fabre himself gives many facts which point in the same direction, but he draws a line between those actions which are the result of mechanical and unvarying instinct and those which come within the sphere of reason, and in relation to which the insect must consider, compare, and judge. Yet this line, even in the light of his own work, is so extremely variable, needing readjustment with every new species and often among the individuals of the same species, that it loses for others the meaning which it has for its author. He himself speaks of certain individuals of the genus Sphex which refuse to be duped when he withdraws their prey to a distance. These, he says, are the élite, the strong-

headed ones, which are able to recognize the malice of the action and govern themselves accordingly, but these revolutionists, apt at progress, he goes on to say, are few in numbers. The others, the conservators of old usages and customs, are the majority, the crowd. Yes, but is it not always the strong-minded few that direct the destiny of a race?

Chapter III

THE GREAT GOLDEN DIGGER

THIS wasp (Sphex ichneumonea Linn.) is one of our most beautiful species, its great size and its brilliant color, as it flies among the flowers, serving to make it well known to all observers of nature. During the later part of July, all through August, and even in the early days of September it is commonly found at work making or storing its burrow. It is rare in our garden, however, and we thought ourselves fortunate in being able to keep track of one individual from the making to the closing of the nest. Although large and powerful it is gracefully formed. In color it is brown, varied with bright yellow.

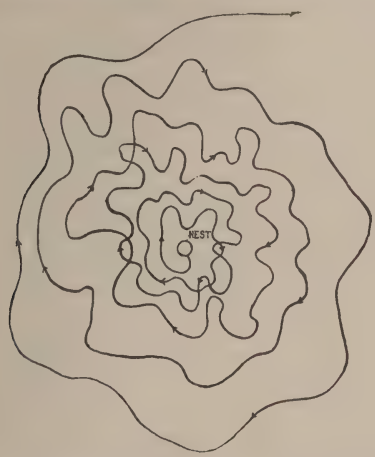
On the morning of the third of August, at a little after ten o'clock, we saw one of these hunters start to dig a nest on the side of a stony hill. After making some progress in the work she flew off and selected a second place, where she dug so persistently that we felt confident that this was to be her final resting-place; but when the hole

was two and one half inches deep, it too was deserted. Again our wasp chose a spot and began to burrow. She worked very rapidly, and at twenty minutes before twelve the hole was three inches deep. At high noon she flew away, and was gone forty minutes. The day was excessively hot, about 98° Fahr., and we ourselves were only deterred from taking a noonday rest by our fixed determination not to leave the place until we had seen all that there was to be seen in the manœuvres of ichneumonea. On returning she appeared very much excited, fairly quivering with vitality as she resumed her work. She came up backward, carrying the earth with her mouth and anterior legs, and went back from the opening some little distance, when it was dropped, and she at once went in again. While in the burrow we could hear her humming, just as the Pelopæi do when, head downward in the wet mud, they gather their loads for nest-building. In five or six trips a little mass of earth would accumulate, and then she would lie quite flat on the heap and kick the particles away in all directions. As the work progressed the earth was carried further and further away before it was placed on the ground, and as she backed in different directions the material brought out was well spread about from the down-hill side of the nest. Sometimes she would spend several moments in

smoothing the débris all around, so that the opening presented much the appearance of an immense ant-hill, only the particles were much larger. During the first hour that we watched her she frequently turned directly toward us, and, sometimes remaining on the ground and sometimes rising on her wings to a level with our faces, appeared to be eyeing us intently for four or five seconds. Her attitude was comical, and she seemed to be saying, "Well, what are you hanging around here for?"

As the afternoon wore on she worked more calmly and her fidgety and excited manner disappeared, the excavation progressing steadily until half-past three. At that time she came out and walked slowly about in front of her nest and all around it. Then she rose and circled just above it, gradually widening her flight, now going further afield and now flying in and out among the plants and bushes in the immediate vicinity. The detailed survey of every little object near her nest was remarkable; and not until her tour of observation had carried her five times entirely around the spot did she appear satisfied and fly away. All her actions showed that she was studying the locality and getting her bearings before taking her departure. A fact that impressed us very much was that with the two nests that she had begun and then deserted she had taken no such precau-

tion, but simply came up and flew off. Had she made up her mind, if we may be allowed to use the term, that the localities were in some way unsuitable and that hence she had no occasion to return to them? Had she



THOROUGH LOCALITY STUDY BY SPHEX

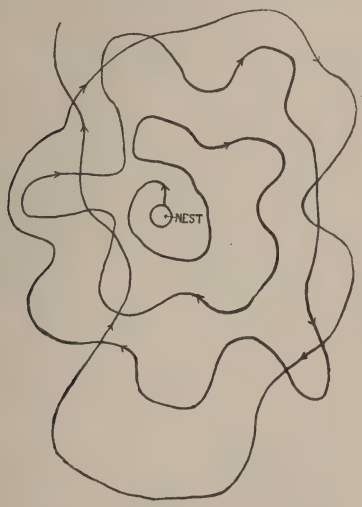
decided, in the last instance, that she would return and so must get her bearings? We wondered how far the different acts were instinctive, or were, as Huber has it, an evidence of a "little dose of judgment." Bates, in speaking of Monedula signata, says that he often noticed it taking a few turns about the locality of its nest, and that he was convinced that it was doing so for the purpose of getting its bearings. Belt, having described

how he fed a specimen of Polistes carnifex with a caterpillar, which the wasp cut into two parts, goes on to say: "Being at the time amidst a thick mass of fine-leaved climbing plant, it proceeded, before flying away, to take note of the place where it was leaving the other half. To do this, it hovered in front of it for a few seconds, then took small circles in front of it, then larger ones around the whole plant. I thought it had gone, but it returned again, and had another look at the opening in the dense foliage down which the other half of the caterpillar lay."[1] He then remarks that when the wasp came back for the remaining half it flew straight to its nest without taking any further note of the locality. Both of these writers believe that many of the actions of insects that are ascribed to instinct are really evidence of the possession of a certain amount of intelligence.

To return to our Sphex. When she flew away we naturally supposed that she had gone in search of her prey, and we were on the *qui vive* to observe every step in her actions when she came home. Alas! when she came back half an hour later, she was empty-handed. She dug for four minutes, then flew off and was gone two minutes, then returned and worked for thirty-five minutes. Another two minutes' excursion, and then she settled down

[1] *Naturalist in Nicaragua*, p. 136.

to work in good earnest and brought up load after load of earth until the shadows grew long. We noticed that on these later trips she flew directly away, depending upon her first careful study of the surroundings to find her way back. At fifteen minutes after five the patient worker came to the surface, and made a second study,



HASTY LOCALITY STUDY BY SPHEX

this time not so detailed, of the environment. She flew this way and that, in and out among the plants, high and low, far and near, and at last, satisfied, rose in circles, higher and higher, and disappeared from view. We waited for her return with all the patience at our com-

mand, from fifteen minutes after five until fifteen minutes before seven. We felt sure that when she came back she would bring her victim with her, and when we saw her approaching we threw ourselves prone on the ground, eagerly expecting to see the end of the drama; but her search had been unsuccessful, — she carried nothing. In the realms of wasp-life, disappointments are not uncommon, and this time she had us to share her chagrin, for we felt as tired and discouraged as she perhaps did herself. When we saw her entering without any provision for her future offspring, we were at a loss what to do next; and it may be that this state of mind was shared by her also, for she at once began to fill in the entrance to her nest. We now thought it time to act, and decided to capture her, to keep her over night in one of our wasp-cages, and to try to induce her to return to her duty on the following day. We therefore secured her in a large bottle, carried her to the cottage, and having made every possible arrangement for her comfort, left her for the night.

On the next morning, at half after eight o'clock, we took Lady Sphex down to her home, and placed the mouth of the bottle so that when she came out she had to enter the nest. This she did, remaining below, however, only a moment. When she came up to the surface

SPHEX DRAGGING GRASSHOPPER TO HER NEST

she stood still and looked about for a few seconds, and then flew away. It surprised us that having been absent from the place for so many hours, she made no study of the locality as she had done before. We thought it a very unpromising sign, and had great fears that she was deserting the place and that we should see her no more. One would need to watch a wasp through the long hours of a broiling hot day to appreciate the joy that we felt when at nine o'clock we saw her coming back. She had no difficulty in finding her nest, nor did she feel any hesitation as to what ought to be done next, but fell to work at once at carrying out more dirt. The weather, although still hot, had become cloudy and so threatening that we expected a down-pour of rain every moment, but this seemed to make no difference to her. Load after load was brought up, until, at the end of an hour, everything seemed completed to her satisfaction. She came to the entrance and flew about, now this way, and now that, repeating the locality study in the most thorough manner, and then went away. At the expiration of an hour we saw her approaching with a large light green meadow-grasshopper, which was held in the mouth and supported by the fore legs, which were folded under. On arriving, the prey was placed, head first, near the entrance, while the wasp went in, probably to reas-

sure herself that all was right. Soon she appeared at the door of the nest and remained motionless for some moments, gazing intently at her treasure. Then seizing it (we thought by an antenna) she dragged it head first into the tunnel.

The laying of the egg did not detain her long. She was up in a moment and began at once to throw earth into the nest. After a little she went in herself, and we could plainly hear her humming as she pushed the loose material down with her head. When she resumed the work outside we interrupted her to catch a little fly that we had already driven off several times just as it was about to enter the nest. The Sphex was disturbed and flew away, and this gave us an opportunity to open the burrow. The grasshopper was placed on its back, with its head next to the blind end of the pocket and the legs protruding up into the tunnel.

We found that the egg of the wasp, which was seven millimeters long, and rather slender, was placed on the under face of the thorax at a right angle to its length, and parallel with the femur of the second leg. This leg had apparently been stung so that it had swollen and folded over the free end of the egg, which was thus firmly held in place at both extremities.[1] Upon examination

[1] Fabre says that all of the three species of Sphex that he has

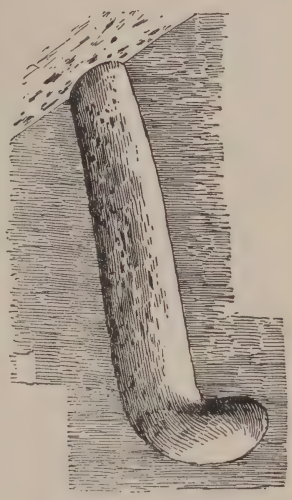
we found that the abdomen of the grasshopper was beating regularly and automatically, but the closest observation failed to discover any other movements, nor would any part respond when stimulated. At three o'clock in the afternoon we found the abdomen still pulsating, and, in addition, that both antennæ moved several times when we lifted off the cover of the jar that contained the insect. On the next morning the grasshopper was very lively, the antennæ and labial palpi moving without stimulation. It had passed fæces, and was able to lift its abdomen, which was curved over toward the head, as it lay on its back, frequently and with considerable violence. On the next afternoon there was no change in the movements, but the egg was dead. On the seventh the grasshopper responded to stimulation by a slight movement of the palpi and the end of the abdomen. The pulsation of the abdomen continued until the afternoon of the eighth, when it ceased, no effort of ours succeeding in starting it again. The movements of the antennæ and palpi grew weaker and weaker on the ninth, and on the morning of the tenth the insect

studied lay the egg on this identical place. He places immense importance on this point, which seems to us rather fanciful. He also noticed the pulsation of the abdomen and the movements of the other parts.

was dead, a period of five and a half days having elapsed since it was brought into the nest.

We had not supposed that the digging up of her nest would much disturb our Sphex, since her connection with it was so nearly at an end; but in this we were mistaken. When we returned to the garden about half an hour after we had done the deed, we heard her loud and anxious humming from a distance. She was searching far and near for her treasure house, returning every few minutes to the right spot, although the upturned earth had entirely changed its appearance. She seemed unable to believe her eyes, and her persistent refusal to accept the fact that her nest had been destroyed was pathetic. She lingered about the garden all through the day, and made so many visits to us, getting under our umbrellas and thrusting her tremendous personality into our very faces, that we wondered if she were trying to question us as to the whereabouts of her property. Later we learned that we had wronged her more deeply than we knew. Had we not interfered she would have excavated several cells to the side of the main tunnel, storing a grasshopper in each. Who knows but perhaps our Golden Digger, standing among the ruins of her home, or peering under our umbrella, said to herself: "Men are poor things; I don't know why the world thinks so much of them."

Dr. Packard describes Sphex ichneumonea as nesting in gravelly walks, where it digs to a depth of from four to six inches, using its jaws and fore legs to do the excavating. While the wasps that he observed completed the hole in half an hour, ours was actually at work a little over four hours. Her nest, as is shown in the drawing, measured seven and one half inches to the beginning of the pocket, which was three quarters of an inch wide by one and one half inches long. The yellow-winged Sphex, a native of France, was found by Fabre to take several hours to make her nest, working in hard ground; while another species, also studied by this observer, dug in soft earth, either in the ground or in the accumulations on the roofs of buildings, and completed her work in fifteen minutes at the most. These variations in the habits of closely related species should be carefully studied in any attempt toward an explanation of their instincts.



NEST OF SPHEX

Fabre's account of the genus Sphex, as it appears in

France, is most interesting. He says that the yellow-winged species, living in colonies, first digs her nest and then secures her cricket, which is brought, on the wing, to the neighborhood of the burrow, the last part of the journey being accomplished on foot. The cricket is dragged by one of the antennæ, and is not left until the nest is reached. It is then placed so that the antennæ reach precisely to the opening, and there it is left while the wasp descends hurriedly into the depths of the burrow. In a few seconds she reappears, showing her head outside, seizes the antennæ of the cricket, and drags it below. These manœuvres are repeated with a striking degree of invariability.

The other Sphex first secures her prey, which is too large and heavy to be carried far, and then digs her nest in the neighborhood of the capture. This being done, she returns to her victim, and straddling it drags it by one or both of the antennæ. Sometimes the whole journey is accomplished at once, but oftener the wasp suddenly drops her burden and runs rapidly to her nest. Perhaps it seems to her that the entrance is not large enough to accommodate a creature of such size; perhaps she imagines some imperfections of detail which would impede the process of storing it up. The work is retouched, the doorway enlarged, the threshold

smoothed. Then she returns to her booty and again starts with it. After a few steps the Sphex seems to be seized with another idea. She has visited the doorway, but has not seen the interior. Who knows whether all is well within? She drops her prey and again runs off. The visit to the interior is made, more touches are given, and once more she returns. Will the journey be accomplished this time? Impossible to say. Some wasps, more given to worry than others or more forgetful of the small details of architecture, to repair their neglect or to clear up their suspicions, abandon their booty five or six times in succession to retouch the nest or simply to visit the interior. The prey, once brought to the nest, is carried in without the preliminaries that are common to the other species.

Chapter IV

SEVERAL LITTLE WASPS

IN a search for the nest of one of our garden wasps we found, in the woods beyond the fence, an old, weather-beaten stump which was riddled with holes both large and small. The large ones were evidently the passage-ways of ants, and were in constant use. The small ones seemed to be uninhabited; but thinking they might contain the nests we were in search of, and hoping that if we watched long enough we might see our wasps flitting in and out, we settled ourselves close by. We were resolved to stay as long as was necessary, and we blessed the fate that made it our duty to sit on the grass under the shade of a wide-spreading oak rather than in the distressing glare and heat of the garden; for this was on the tenth of July, and the weather was what the farmers call "seasonable."

Twenty, thirty, forty minutes passed. Our eyes ached with persistent gazing, and we had nearly made up our minds that the likely-looking little holes were untenanted, when lo! a tiny wasp, carrying something which

we could not see distinctly, darted into one of them. It was gone so quickly that we could not be sure that it was the species we were looking for, and when it reappeared, after two or three minutes, we saw that it was not. This point being determined, we watched the hole with redoubled interest.

It was wearisome work, for the wasp stayed away a long time, and we dared not let our gaze wander lest she should slip in without our knowledge. At the end of thirty-five minutes she returned, but again we failed to see what she carried. She flew with great rapidity, and we scarcely caught sight of her before she vanished into her nest. We could not but wonder at the ease and certainty with which she recognized her own doorway among the hundreds of holes on the side of the stump. This power of localization, while it is one of the most common among wasps, is surely also one of the most remarkable.

Our little Rhopalum pedicellatum, for that proved to be her name, made six more journeys within the next two hours. At the end of this time we opened the tunnel, and, after a great deal of sawing and cutting, succeeded in finding the nest five inches from the surface. It was nothing but a slight enlargement of the gallery, in the soft decaying wood. In it we found thirty-three gray

gnats, all of them, except two, being dead. On one of the dead ones was the egg, which had probably been laid within a few hours.

The egg hatched two days later, on July twelfth, but on the fifteenth the larva died. By this time many of the gnats looked very dry, although we had tried to arrange for both moisture and ventilation by packing the bottom of the tube with pith and covering the top with muslin.

Further watching gave us one more wasp of this species, in the same stump. This time the nest was only two inches from the surface. It contained four dead gnats and two live ones, but no egg, showing that the egg is not always laid on the first ones stored.

Much later in the season, toward the end of August, we found another species of Rhopalum which proved to be new, and for which Mr. Ashmead has proposed the name rubrocinctum, since it wears a red girdle around the front end of the abdomen, being otherwise dressed in black like pedicillatum. It makes its home in the stalks of raspberry bushes. We opened a stem which contained thirteen compartments, separated by partitions of pith. These were filled with black, gray, and green gnats, which were packed in so closely that they were doubled over and pressed out of shape. Each cell contained from twenty-five to thirty gnats. In some of them were

cocoons, in others larvæ, and in one was an egg. The gnats were very carefully examined, and all of them, from the cells that had been filled last as well as from those provisioned earlier, were dead.

Other species of Rhopalum are said to prey upon spiders and aphides.

In studying the species that come in our way we are continually developing distinct likings for some kinds above others. The appearance of one of these favorites is always hailed with delight, and when the season's work is over we remember them with lively pleasure.

OXYBELUS QUADRINOTATUS

It is thus, dear little Oxybelus, that we dwell upon the thought of you and your pretty ways. No other wasp rose so early in the morning, no other was so quick and tidy about her work, so apt and business-like without any fuss or flurry. No other was more rapid and vigorous in pursuit of her prey, and we think with admiration and gratitude of the number of flies that you must have destroyed in the course of the summer.

O. quadrinotatus is only one-quarter of an inch long, and is dark gray with four whitish spots on the abdomen. It was before nine o'clock in the morning that, while out on an early inspection tour in the garden, we saw one of these wasps descend upon a sandy spot, and after a moment's rapid scratching with her first legs enter the hole that she had opened. Under her body she was carrying a fly which looked like the common domestic species. It was upside down, its head being tightly clasped with the third pair of legs, and all of its abdomen projected beyond the abdomen of the wasp. Ashmead quotes from Fabre the remarkable statement that Oxybelus carries her flies home impaled on her sting, an idea that probably arose from the fact that nearly the whole body of the fly is visible.

Our new-found wasp stayed only a moment in her nest, although, as we afterward found, it was long enough for her to lay her egg on the fly. When she came out she quickly smoothed the sand over the spot with her head and legs so that there was nothing to mark the nest, and flew away. In three minutes she returned with another fly. She alighted two or three inches away, and scratched for an instant, but quickly saw her mistake, and found the right spot.

Again and again the pretty little worker went and

came, while we sat watching close by, admiring her deft handiwork in opening and closing the nest and wondering at the ease with which she found it at each return. There was nothing tiresome or dilatory about this species, and within twenty minutes we had seen six flies stored up. The nest was closed and the place smoothed over every time before she went away, but when she entered she left the door open behind her. We once tried to make her drop the fly, but when disturbed she flew up and alighted on a plant near by, keeping her hold on it. The whole performance was brisk and business-like, but without the feverish hurry of Ammophila and Pompilus.

After the sixth fly was taken in we were afraid to let her go again, thinking that the nest must now be completely provisioned, and that she would not return. She was such a charming little wasp, scarcely bigger than a fly herself and yet so useful in her industry, that we hated to disturb her; but as we were obliged to have her for identification we first caught her, and then opened the nest. It contained only the flies that we had seen taken in, the egg being attached to the one lowest down, on the left side, between the head and the thorax. It was long and cylindrical. The flies were dead, but showed no marks of violence. We learned later that it takes

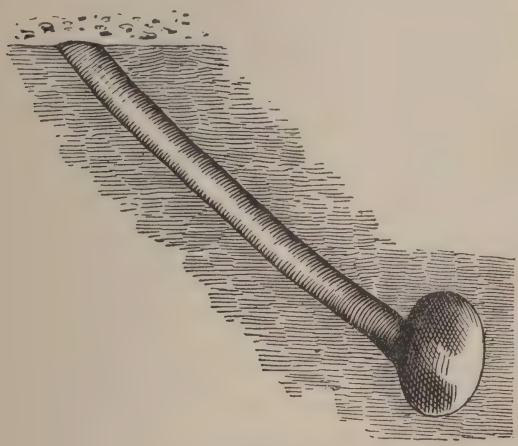
Oxybelus two hours to make her nest so that this one must have been prepared the day before.

The egg, which was laid just before nine o'clock on the morning of August seventh, hatched at a little after nine on the morning of August eighth. The larva began to eat at once, and devoured all the inside of the thorax and abdomen of the fly to which it was attached, in the first twenty-four hours. On August twelfth it had reached the sixth fly, and we supplied it with three more. On August fourteenth these were gone, and we again replenished its larder, this time with two flies. The larva had partly eaten these when something went wrong. Its appetite failed, and on August sixteenth it died.

On further acquaintance this wasp lost none of her charm, — indeed, she gained in interest from the almost human curiosity that she showed about the affairs of other people. Where several were living close together one of them would sometimes stop digging her own nest to perch on a weed and watch the labor of another, and we once saw an especially inquisitive character burrow through the closed door and enter the home of her next-door neighbor.

We find but meagre notes on the genus Oxybelus. Ashmead says that no observations have been made on the American species, but that in Europe they are found

to burrow in sand and to provision their nests with dipterous insects. He says also that according to Verhoeff the species in this genus do not paralyze their prey by stinging, as they are unable to do so on account of the



NEST OF OXYBELUS

rigidity of the abdomen, but that instead they crush the thorax with the mandibles just beneath the wings, the centre of the nervous ganglia. He found in one nest a dozen flies, and all had the thorax crushed and were dead. In the case of our wasp we do not know how the flies were killed, but there was no crushing of the thorax. The larva devoured, in all, ten flies. At the time of its death it had probably finished the larval stage of its

existence, since nine days had elapsed since the hatching of the egg. It may be that this period just before pupation is a critical point in the life history of a wasp, for we lost several of our nurslings at this time, and Fabre has noted that when, on account of the presence of parasites, the larva of Bembex rostrata had lacked something of its usual amount of nourishment, it perished miserably at the end of its larval stage, not having strength enough to spin its cocoon. No waspling in our charge ever died from lack of nourishment — on that score our consciences are clear ; but it was difficult to make their conditions quite normal, and for this reason we may have been, indirectly, the cause of their death.

The way in which our Oxybelus carries its prey is peculiar to itself. Bembex and Philanthus also hold their prey under the body, but use the second pair of legs, so that it does not project behind except at the moment of entrance into the nest. Quadrinotatus, as we could distinctly see, since she passed close to us several times in quick succession, clasps the head of her victim in the third pair of legs, and flying thus, with its whole body sticking out behind her, she certainly presents a very remarkable appearance.

Aporus fasciatus is a dark gray species, and is less than half an inch in length. We were working one hot day in

the melon field, when we saw one of these little wasps going backward and dragging a female of Mævia vittata which was much larger than she was herself. She twice left it on the ground while she circled about for a moment, but soon carried it up on to one of the large melon leaves, and left it there while she made a long and careful study of the locality, skimming close to the ground in and out among the vines; at length she went under a leaf that lay close to the ground and began to dig. After her head was well down in the ground we broke off the leaf that we might see her method of work. She went on for ten minutes without noticing the change, and then, without any circling, flew off to visit her spider. When she tried to return to her hole it was evident that some landmark was missing. Again and again she zigzagged from the spider to the nesting-place, going by a regular path among the vines from leaf to leaf and from blossom to blossom, but when she reached the spot she did not

APORUS FASCIATUS

recognize it. At last we laid the leaf back in its place over the opening, when she at once went in and resumed her work, keeping at it steadily for ten minutes longer. At this point she suddenly reversed her operations and began to fill the hole that she had made, kicking in the earth until the entrance was hidden. She then glanced at the spider, selected a new place, and began to dig again. Surprisingly large pellets of earth were carried out, backward, and loose dirt was kicked under the body by the first legs. At the end of two or three minutes she paused and remained perfectly still for a time, considering the situation. Her conclusion was adverse to the locality, for she soon filled in the hole, looked once more at the spider, and started a third nest in a new place. This in turn was soon abandoned, as was also a fourth. The fifth beginning was made under a leaf that lay close to the ground, so that we could not see her at all. Fasciatus! had we had the naming of her she should have gone down the ages as exasperans! We had now watched her for an hour in the intense heat; the bell for the noonday meal had sounded, hunger and thirst had descended upon us, and most devoutly did we hope that she was suited at last, but no — after twenty minutes' work this place also was abandoned, and a sixth nest started. This, however, was the final

choice, and after forty-five minutes spent in digging, it was completed. As the spider was brought toward the nest it was left again and again while the nervous little wasp flew to the hole, went in, examined, and came out again. At last she backed in, caught the spider by the abdomen, and dragged it down. It was too big — the head stuck in the hole; but she pulled from below while we pushed gently from above, and it slowly disappeared. When she came out we opened the nest and took the spider. The egg was fastened to the middle of the left side of the abdomen. This one, as was also the case with a second and third afterward taken from fasciatus, was much less affected by the poison than is usual among the victims of solitary wasps, moving from the time it was taken, without any stimulation, and improving rapidly from day to day. Our second spider appeared to be blind, and died upon the sixteenth day, while the third had entirely recovered by the seventeenth day after it was stung, and was released. Fasciatus, then, probably depends upon packing her victim in tightly to keep it quiet.

It was three days and a half before the egg that we had taken hatched. The larva developed rapidly, retaining its hold at the spot to which the mother had fastened it. The spider remained alive for six days, and the larva

continued to grow for two days longer, when it died also, being at the time about two thirds grown. We had great trouble in protecting our growing larvæ from the inroads of fungi, and this was one of the many that perished from that cause.

The next example of fasciatus that came under our notice was a remarkable contrast to the one that we have just described, being as slow and dignified as the other was nervous and hurried. She chose a place and kept to it, her steady labor being interrupted only by occasional visits to the spider; but it took her fifty minutes to complete the nest. When finished it was a small gallery running down obliquely for an inch and a half into the ground.

The only habit that this species can claim as peculiar to itself is the strange and useless one of filling up the partly made nests that it is about to abandon. We have never seen the sense of order carried to so high a point in any other wasp.

On a hillside near our cottage stands a log cabin, deserted and untenanted save for small creatures of the wild, which, though a favorite spot with wood-boring wasps, is an unprofitable place for study because of the difficulty of cutting out their nests without destroying property. One day in early July, however, when we

WASP HOMES IN THE LOG CABIN

were in the full fervor of hunting and longed to utilize every moment, the wasps in our garden seemed to have resolved that enjoyment and enjoyment only was their destined end and way, and became so exasperatingly idle that in disgust we turned to the cabin. For half an hour we saw nothing more exciting than a Trypoxylon immuring her victims and a Pompilus hunting spiders under the eaves, but at the end of that time Passolocus annulatus, a tiny wasp new to us, came flying quietly along and entered one of the holes with which the ends of the logs were riddled. She was carrying an aphis in her mandibles, and when this was duly stored she reappeared and flew away. She had probably just renewed her work after a spell of rest, since from this time on for nearly an hour she came back regularly every four or five minutes. She nearly always alighted on a blade of grass before going into the nest, but did not appear to be malaxing her prey. Presently another stage in the game was reached. She no longer brought aphides, but little pellets of mud with which she plastered up the opening. After she had finished this task and departed, we carefully chiseled into the log and laid bare the nest. The tunnel ran in for about three inches, and ended in three pockets which were well stocked with dead aphides, there being fifty-seven in all. The innermost cell con-

tained a larva, and in the others were eggs, one of which hatched on the next day and one on the day following. This second one was probably laid just before the nest was sealed, giving forty hours for the egg stage; and it proved to be the healthiest of the three. The others perished in early infancy; but this one passed twelve days in eating, not only its own share of provisions, but those destined for the other members of the family as well, and then spun its cocoon.

We afterwards saw many of these wasps working in the logs of the cabin, and noticed that they seemed to have seasons of leisure alternating with spells of active work, as though when one cell had been filled up and the egg laid they felt at liberty to amuse themselves for a time before beginning on another. When an entirely new residence was to be chosen they went house-hunting among the old holes in the logs; and whether they had a high standard of sanitary conditions, or whether they objected to making extensive repairs, a great many places were examined and rejected before they settled down. The choice once made, many loads of pith were carried out before the little householder was satisfied. After the new abode was put to rights, the wasp would pass a whole day in rest, spending much of the time in looking out of her doorway and perhaps in observing

the doings of her neighbors, but when she began to work she was very industrious, and allowed nothing to interfere with her labors, paying no more attention to us, no matter how closely our curiosity led us to interrogate her, than if we had been trees blown about by the wind.

Some of the wasps dig deep into the stems of bushes to form galleries for their nests, but we found one wise genus that went in only far enough to make one or two cells, thus saving the trouble of carrying her cuttings thirty or forty centimeters in direct opposition to the force of gravity. This was Odynerus, whose nests we found in July, in blackberry and raspberry stems. Our first species was perennis, whose nests bear her mark in the shape of a pellet of earth placed above each mud partition. One of her cells contained a wasp larva and about sixteen caterpillars, nearly one third of which were dead, while the rest were more or less lively. They seemed to have been stung near the anterior part, as the last three or four segments were jerked up violently when touched. The larva went on eating, and the caterpillars went on dying from hour to hour. At the end of the eighth day, the baby wasp finished

NEST OF PERENNIS

its meal, having eaten all that had been provided for it, as well as two dead caterpillars from another nest.

Much interest attaches to the way in which Odynerus lays her egg, since instead of following the common fashion of fastening it to the prey she suspends it by a tiny filament of web from the wall or ceiling of her cell. Thus in O. reniformis, nesting in the ground, it is hung from the ceiling, a mass of very imperfectly paralyzed caterpillars being collected below, and when the larva comes out the thread lengthens until the tiny jaws reach the food supply. Startle it ever so slightly and the wasp-ling retreats by way of its web, descending again only when everything is quiet. For twenty-four hours it retains this path to safety, and then, growing bold, it drops down and feeds at its ease.

We had opened hundreds of plant stems in quest of these suspended eggs without being so fortunate as to find one, and were therefore much pleased when our kind friend, Dr. Sigmund Graenicher, whose interest in bees keeps him in touch with out-of-door happenings, and who has given us much valuable help, brought us two stalks, one of which had in it a nest of O. conformis, while the other contained two freshly provisioned cells of O. anormis. In all three the egg had been hung from

the side of the cell about one third of the way down, and in the nest of conformis, from which all but one of the caterpillars had fallen, it hung loose against the wall. In the other nests the lower part was packed tightly with sixteen small larvæ, upon which lay the egg, supported in a horizontal position, although attached to the side wall exactly as in conformis, and above were eight more caterpillars, the whole forming a compact mass shut in by the usual partition of mud. So closely were they crammed in that after counting them we were unable to get them all back again, and although motionless in their narrow quarters they became quite active when relieved from pressure. This is an entirely different arrangement from that of O. reniformis, and since the larva is in contact with the caterpillars from the moment of hatching the manner of the egg-laying has no significance in relation to the safety of the young.

NEST OF ANORMIS

Conformis hatched on the morning after we received it, sloughing off the skin of the egg, but remaining attached to it, and thus doubling the length of the thread by which it hung. The caterpillar was slightly separated from it, and it seemed to have no notion of feeling about

for its food, eating nothing for twenty-four hours, but growing and developing nevertheless. We now piled up some caterpillars in contact with it, and it began to eat, but after its own caterpillar and as many as we dared take from anormis were gone it stubbornly refused to take soft, tender little spiders, or caterpillars out of our garden; and it perished, a victim to prejudice.

The two eggs of anormis were probably laid within a few hours of each other, since they had both hatched on the morning of the third day, and had broken from their attachment, beginning to eat at once. They cocooned on the fifth day after hatching.

We had long wished to find a nest of O. capra, and early in September fortune favored us. A neighbor of ours keeps a large tin horn hanging under the porch. One day when she wished to use it, no amount of blowing would bring forth a sound; and when she unscrewed the mouthpiece to investigate the matter, out tumbled several small green caterpillars and a quantity of dry mud. When we heard of this incident we begged that if it should be repeated the nest and its contents might be saved for us; and on the second of September we received the mouthpiece of the horn with a message to the effect that a wasp had been working at it for some days. Examination showed that there were three cells,

each containing a larva and a supply of caterpillars, of which there were ten in the cell most lately formed, and only one left uneaten in the oldest. The caterpillars, all of them being alive, together with the wasp larvæ, were transferred to a place in which they could be conveniently watched. None of the caterpillars died until they were attacked. The larvæ ate all the food that was provided, the oldest one cocooning on the fourth, and the second one on the seventh of September. Of the third, we have no record, excepting that the caterpillars had all been eaten on September eighth.

We happened to be passing through our neighbor's grounds at nine o'clock on the morning of September fifth, and calling to ask whether there had been any more visits from the wasp, we learned that capra had been seen making a mud partition in the horn on the day before. While we were speaking she arrived and entered the mouthpiece, where she remained for about ten minutes. When she departed we found that she had laid her egg, which we carried away with us, wishing to determine the length of the egg stage. This proved to be longer than that of any wasp that we had heretofore known, for not until the morning of September ninth did the larva make its appearance, the egg skin bursting and leaving its tenant free to crawl away. In

other genera the egg changes into a larva imperceptibly, there being no sloughing off of the skin.

Capra, then, first finds a suitable crevice, and builds a partition across the inner end, the earth being scratched up from some dry, bare spot, and moistened in her mouth. Before gathering the ten or twelve small caterpillars that are to provision the cell, she lays her egg; and although we could not be sure, we thought that in this case as in the others it was suspended.

Unless the cell is tightly packed at the beginning, capra certainly needs the filament, for her caterpillars were so far from being reduced to a state of decent immobility that we had to press wads of cotton into the tubes in which they were kept to prevent them from wriggling out of the way of the larva. None of our larvæ, not even the one-day-old ones, were injured by their activity; but had the egg been left to its fate among them it might have perished.

Later in September we found O. vagus bringing pellets from a sharp-edged hole in the ground. Her method was to carry each load on the wing to a distance of ten or twelve inches, where it was dropped without the lively fling with which Ammophila discards her lump of dirt. The red end of a match stuck into the ground two inches away proved very disquieting to the dainty little

wasp. These colored matches were a great convenience in marking nests, and as we were using them constantly, we did not guess, for a time, what the trouble was. For half an hour she went and came, circling about, alighting upon plants, and seeming entirely absorbed in examining them with the minutest care, even alighting upon our hands with most engaging friendliness, but pretending all the time that the nest was naught to her. When the offending object was removed she hurried in at once and resumed her work. The storing was not begun until the next morning, when she took in six caterpillars of very different sizes, at intervals of from ten to twenty minutes, and then filled the hole. We hoped to find the little chamber arranged as in reniformis, but had not skill enough to excavate in such a way as to show the internal plan. It is remarkable that this genus, with only one set of tools for all its species, has worked out such different styles of architecture, the ground nests bearing no resemblance to those cut out of woody stalks; and its flexibility is shown in the use of empty snail shells by a foreign species, as well as by capra's habit of partitioning off convenient crevices found ready made.

The prettiest nests that we have seen in stems are those of Plenoculus peckhamii, which separates its

cells, not by solid partitions, but by numerous granules of earth, which are used by the larvæ for forming the case of the cocoon. One raspberry stalk that we opened had at the bottom six of these mud cocoons, and above these three larvæ eating, each in its own compartment, the provision in this case consisting of immature bugs of the genus Pamera. Sometimes the stalk which is being filled by Plenoculus attracts the fancy of a bee or of another wasp, as is shown by the upper cells being filled by Osmia or Crabro, or sometimes Plenoculus builds above the bee cells. When a number of wasp eggs are placed in a plant stem, the last one laid is the first to hatch. The different habits of the Hymenoptera in this respect are very interesting. In the case of Ceratina dupla, the small carpenter bee, the egg first laid hatches first, those above following in regular order. The lower ones wait patiently in their cells until the one in the top cell has matured, and then they all come out at once. When two species occupy the same stalk, the lack of adjustment probably results in the destruction of those lower down, excepting in the case of the cuckoo flies, which have acquired the habit of gnawing their way out at the side of the stem.

Chapter V

CRABRO

THE highest point of the island is crowned by a great group of linden trees; and one day their perfume, carried by the wind far over field and wood, was calling everything that had wings to gather the richest of all the gifts that July can offer. We, too, were drawn to the spot, and found the great blossoming domes thrilling and vibrating with life. For miles around, the bees, wasps, and butterflies had gathered to the feast; and we seemed to touch the high-tide of the year in the scent of the flowers, the humming throng of happy creatures, and the vision of it all against the summer sky.

Below, in a great root that had pushed above ground, five little wasps, by name sexmaculatus, of the worthy but unimaginative genus Crabro, resisting the intoxication of the linden flowers, were sawing and cutting in the most humdrum and practical manner. One of them, presumably the earliest riser, was well down in the root, and came backing up once in a while, pushing

a lot of wood dust out of the hole. This was spread out by means of legs and mandibles, and was then blown away by the fanning wings of the little worker, who circled about just above the ground until the last grain had disappeared. Here was another way of protecting the home. The fresh dust might attract the attention of some cuckoo-like insect who would lay her egg within; and therefore it was dispersed, just as Ammophila carried out her pellet and flung it to a distance, and Sphex spread evenly over the ground the mass of earth that she carried from her hole.

After this series of actions had been repeated several times the wasp flew away to hunt. We afterward found that she had finished the third in a set of cells leading from a main gallery. On her return we delayed her to see what she was carrying. She showed no fear, but alighted close by, and while she was trying to transfer to the third pair of legs the fly that she was clasping with the second pair, it escaped and flew gayly away. Flies are plenty, however, and she soon had another which she was permitted to store; and from that time she worked busily until we left her at noon. It took her from two to ten minutes to catch her fly, and at each return two or three minutes were spent in the nest. On opening her tunnel some days later, we found within

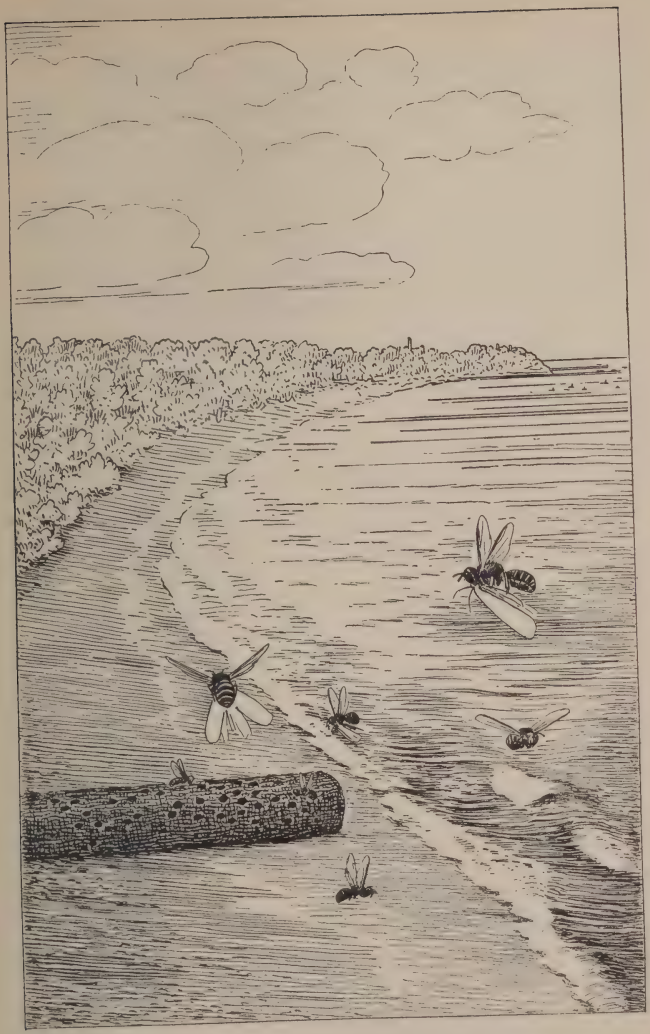
SEXMACULATUS IN THE LINDEN ROOTS

not only flies, but long-bodied gnats, and all of them seemed to have been brought home uninjured. When the freshest cell was opened some flew away, others were walking about, and all were lively. The wasp egg was laid on the under side of the neck; and although we could not be certain of the exact time of laying we thought it hatched at the end of thirty-six hours. From ten to sixteen flies were provided for each larva.

A month later we found Crabro lentus nesting in the ground. Her tunnel ran down obliquely for six and one half centimeters, and had an enlargement at the end. Two bugs and a fly were in the nest, when we opened it before the provision was completed. To find sexmaculatus taking both flies and gnats was surprising, so rigid are the family traditions of the wasps; still, she might feel that so long as she drew the line at Diptera she was all right. But to believe that one wasp, a Crabro, too, with all the marks of conservatism about her, would take such diverse things as bugs and flies, is almost too much to believe. It is true that Crabro wesmæli is said to use both flies and bugs;[1] but some accident may have led to this supposition, and stronger evidence is needed to prove that there is variability in so deeply seated an instinct.

[1] Sharp, *Insects*, page 130.

The Crabro wasps all have pleasant ideas as to where they want to live, but interruptus excels in the choice of a dwelling place. We lately found ten or twelve of them in Milwaukee, nesting in an old log on the shore of Lake Michigan, and when they opened their doors in the morning they had before them the splendor of the great bay; but calm in the midst of the glory they never paused on the threshold, as Cerceris would have done, to take a look at the world before going to work. One morning the earliest riser in our little colony was beginning the day at half past nine. Of good size for a Crabro, with a square determined-looking head and very direct and business-like manners, she proceeded to cut out a new chamber for provisioning. These chambers are nothing more than enlargements of the long gallery, such as are made in stems by related species. At ten o'clock she departed on a hunting excursion among the bushes on the bank above us, and came back in eight minutes, carrying, much to our surprise, a white-winged moth, which was clasped under the body by the second and third pairs of legs, and was passed back to the third pair as she alighted before entering. A moth is an innovation, a delicacy new to the accepted idea of what a Crabro larder, accustomed to Diptera, should contain. A moment later she was off again, but this time did not



CRABRO AND HER WHITE MOTHS

succeed so quickly, coming back twice empty-handed for brief visits, and bringing in a load at the end of half an hour. It took six moths to provision the cell, and as the number neared completion her interest and energy seemed to wax greater, the hunting intervals shortening to five, and even to two minutes. We found afterwards that some of the moths were alive and some dead, and that she packed them lengthwise, one after another, into the closely fitting chamber. At a little before eleven o'clock the cell was filled, and the wasp retired from sight, closing the door behind her. We thought that she was resting, but presently the protrusion of wood dust showed that she was enlarging her house, and an hour later she came out and began to hunt again. By this time half a dozen were working. Before leaving for the first time in the morning each one made a thorough study of the place, and on returning they entered their own doors, which were standing open, without hesitation, the long white wings of the moths trailing behind them. Four species were represented in the nests that we opened.

Many species of Crabro make their nests in the stems of plants, and among these is stirpicola, which is seen in numbers, through the middle of July, flying about in a leisurely way, though it is only toward the end of the

month, or in the early days of August, that they settle down to the work of making their homes. On the afternoon of July twenty-seventh, after some very lively work in the heat of the day, we walked down to the berry garden at half past five o'clock, rather to rest ourselves than with the thought of undertaking anything new; but a wasp-hunter cannot afford to choose his own hours, and we thankfully accepted the sending of fortune when we came upon a stirpicola busy at work in digging out her nest. She had only begun to excavate, and had reached a length just equal to that of her own body. Her manners were an agreeable contrast to those of the wasps that we had been watching through the day. The feverish excitement of their ways seemed quite in keeping with the burning heat of noon, while Crabro's slow and gentle movements harmonized perfectly with the long shadows of evening. To fully appreciate the difference between Pompilus or Ammophila and Crabro it is necessary to see them at work. The one is the embodiment of all that is restless, vying with the humming-birds in swiftness and energy, while

CRABRO STIRPICOLA

the other is calm, quiet, and stately in all that she does.

Some ten feet away was a second stirpicola, and this one, to judge from the depth to which she had penetrated, must have been at work for about two hours. We watched them both, and saw them bring up load after load of pith. They bit out the pellets with their mandibles, and passed them back between the legs and under the body until a quantity had accumulated above the tip of the abdomen. They then walked backward up the stem, and thus pushed out the mass as they came to the top. Often they used the hind legs to assist in getting it out of the way, sometimes kicking it to a little distance. Once in every two or three trips they would come out far enough to expose part of the thorax. They appeared and disappeared with the regularity of a machine, never stopping to rest.

BOTTLE ON STEM TO MEASURE WORK OF CRABRO

We remained with them until seven o'clock, when we placed a long bottle over each stem in such a way that while it did not interfere with the work of the wasp, it caught the chips of pith as they

fell out. At the end of an hour we noted the amount of accumulation in the tube, and thus had a measure of their rate of work. The drawing gives an idea of the arrangement of the tube on the stem. When we left them they were still digging and delving.

At half past nine we took a lantern and went down to visit our charges. We expected to find them at rest, and asleep; but on the contrary they were working as busily as ever, and upon examining the measuring glasses we found that they had not paused since we left them. We measured the depth of the débris in the bottles, and then emptied them.

At four o'clock on the next morning we went to the garden, and were much surprised to find that the two wasps had worked without intermission throughout the night. Indeed they seemed to have shortened a little the time that it took to make a round trip down the gallery and up to the opening again, since there was more pith in the bottles than we could have expected if they had worked at only their former rate. Neither the coolness of the air nor the darkness of the night had made the slightest difference to them. After watching them a few minutes, and marveling at their powers of endurance, we cleared out the tubes and returned to bed. At half past eight we found them still

at work. Unlike us, they had taken no morning nap, but had gone on with their tunneling in their usual steady way.

From this time their ways diverged, and they must be described separately. At nine o'clock the one that we had first seen came up to the opening, walking head first, and flew off, remaining away seven minutes. When she returned she at once resumed her work, and kept at it without a pause until two in the afternoon. At this hour she went away, and we never saw her again. We suppose that she was killed, for it seems improbable that so faithful a creature could have deserted her half-finished home. Pompilus quinquenotatus often deserted a partly finished nest for some more enticing spot, and Sphex started several excavations before making a final choice; but we cannot believe that there was anything fickle about Crabro.

The second wasp came up head first to the entrance of her hole at two minutes after nine, as though she had been influenced, in some subtle way, by her neighbor's example; but after looking about for a moment she went back. She repeated this observation several times, and finally, at twenty-five minutes after nine, came out and flew to a leaf near by. Then she circled around, alighting a number of times, and at last

departed. Her stay was brief, for at just thirty-five minutes after nine she returned, and at once settled down to her work.

We now began to make notes as to the length of time that it took her to go down and bring back her load. We timed her again and again, and found that she was remarkably regular, each of her trips occupying from forty-five to fifty seconds.

All that day we kept her under strict surveillance, and never once did she suspend her operations either for rest or refreshment. Late in the afternoon, while we sat watching her as she appeared and disappeared with almost the regularity of clockwork, we found it difficult to realize that the patient little creature had been at work for more than twenty-four hours, with only one brief intermission. Without hurry or flurry she kept at her task, reminding us, in her business-like ways, of the social wasps of the genus Vespa. When we left her, at dusk, we attached the recording tube to the stem, and at ten o'clock in the evening we found that she had not stopped working. We emptied the glass, and left her.

At seven o'clock in the morning of July twenty-ninth we paid her a visit, and could scarcely believe the testimony of our senses when we saw that the record was one

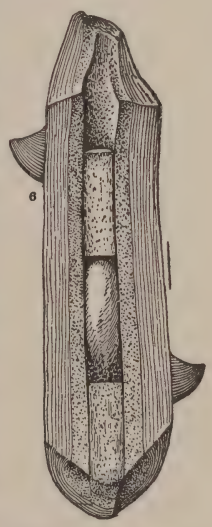
of unceasing toil through the long hours of the second night. We began to wonder if she would ever finish her task. Wonderful though she was, we had grown a little weary of our long session of watching. We had been glad that she worked through the first night; it was creditable to her and interesting to us, and we admired her even more for sticking to it through the second, but when it looked as though we might have to remain by her side through another long day, watching an endless series of loads as they were carried out, we confess that we thought she was rather overdoing it. Gradually, however, she slowed up her work, taking two or three minutes to make a journey down and up. At last, at just nine o'clock, her head appeared at the top of the stalk, and after a slight hesitation she flew away. The nest was completed.

We have studied wasps for a number of years, and we feel that we are on terms of more or less intimacy with many of the species, but never before have we known one to work after day was done. We have often gone out with a lantern at bedtime for a tour of inspection among our nests, and have always found the inhabitants quiet and presumably asleep. The social wasps are very industrious, but during the hot nights of July they are to be seen clustered together on the outside of their paper

nests in deep repose; and although the Vespa wasps that nest in the ground sometimes come home late in the twilight, we have never seen them work after it was really dark. Polistes fusca may be said to share our cottage, so thickly does she hang her combs under the shelter of our porches, and from observations taken at all hours we know that she is quiet through the night. Sir John Lubbock, in "Ants, Bees, and Wasps," speaks of the great industry of wasps. He has known them to work from early morning until dusk without any interval for rest or refreshment; but here was our little Crabro toiling from three in the afternoon of July twenty-seventh, through that night and the day and night following until nine o'clock on the morning of the twenty-ninth, — a period of forty-two consecutive hours with one intermission of ten minutes on the morning of the twenty-eighth. Surely she takes the palm for industry, not only from other wasps, but from the ant and the bee as well.

The nest was completed, but the work of storing it remained to be done. The wasp flew away at nine o'clock, and ten minutes later came back with something, we knew not what, for she dropped into her hole so quickly that she was out of sight almost before we knew she was there. Two minutes later she came up,

and was off again. This time she was gone twelve minutes, and when she returned we were again baffled in our effort to see what she was carrying. When she came out she alighted upon a leaf and attended to her toilet, cleaning both body and wings by rubbing them off with her hind legs, and from this time on she never started on a hunting expedition without paying this attention to her personal appearance. On her third trip she was gone twenty minutes, coming back with a small fly; and before we left her at ten o'clock, she had stored six more. When we came back at half past two in the afternoon she was working, and she kept up her goings and comings until four o'clock, when she suspended operations for the day. On the next morning we were called away, and know nothing of what she did, but on the following day, Thursday, we resumed our observations. She worked hard all the morning, but in the afternoon her trips were few, and were made at long intervals. On Friday she worked from eight to nine, when she departed, and never returned. We

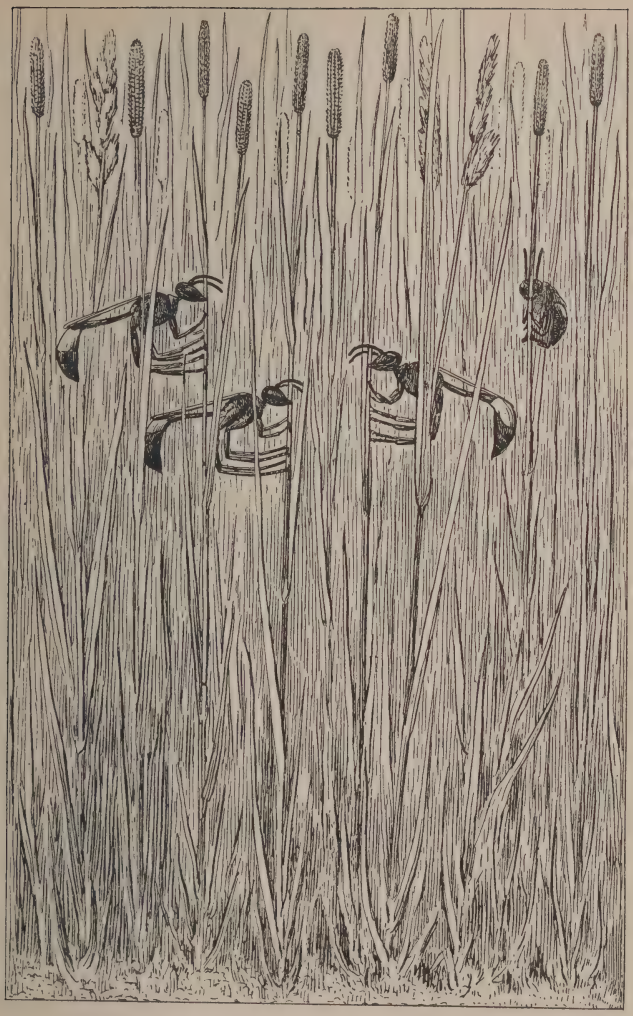


NEST OF C. STIRPICOLA

watched for her, at intervals, all through that day and the next, when we were forced to conclude that our faithful little worker had fallen a victim to some bird or beast. We did not disturb the nest until four days later, when we cut the stalk, and examined it.

We found that the tunnel was thirty-nine centimeters in length. This was a long distance for her to excavate, and, all things considered, her progress had been rapid. We have opened a number of stems that had been stored by this species, and all the excavations were from thirty to forty centimeters in length, the width of the gallery being about three and one half millimeters, while on each side there was from one to one and one half millimeters of pith that had not been cut away. Of course these points varied with the diameter of the stem and also with the size of the worker.

Our little stirpicola had stored one cell, had laid an egg, and had built a partition of pith across the stem as a floor to the second cell, before her untimely taking off. Had she lived, ten or twelve cells would have been stored, one above the other. The completed cell contained a larva and parts of eighteen flies of different sizes, four species being represented. The flies had all been attacked by the larva, the abdomens of some and the thoraces of others having been eaten. The larva continued



AMMOPHILA SLEEPING IN THE GRASS (AFTER BANKS)

to eat for two days, and then spun its cocoon. The flies found in this and in other nests of stirpicola were all dead. All the pupæ that we kept wintered in the cocoon and came out in the spring.

The females of Crabro, like those of other genera, seem to use their galleries as sleeping places, but the males stop at any convenient inn. We once entertained one of them for several nights in a hole in one of the posts of our cottage porch. Other males, as in Philanthus, spend time and care in digging a hole in the ground, to which they return night after night. In Agenia the female keeps one cell ahead of her needs, and tucks herself away in it very comfortably; but the Pelopæi, instead of making this use of their tubes, congregate in the evening where there are convenient crevices, and make as much fuss about getting settled as a lot of English sparrows. Mr. Banks has made a delightfully pretty as well as interesting observation on the sleeping habits of Ammophila. In a corner of his garden where the grass grew long, dozens of these wasps arrived every evening, and after a good many changes in position, fell sound asleep, clinging to the stems about one third of the way down. They registered at this hotel between seven and eight o'clock, and departed before five in the morning. We have seen a Pompilus take the greatest

care in selecting a sheltered spot under some leaves, where she afterward hung herself up, and slept soundly until after eight the next day; and Mr. Brues has found companies of Priononyx atrata passing the night on the stems of sweet clover.

Chapter VI

AN ISLAND SETTLEMENT

OUR children often made themselves useful by reporting finds in the shape of nests, and one day they returned from the island with a wonderful tale of great numbers of big wasps that were digging in the ground. "I don't know what they are," said the small boy, "but they act to me like the maddest kind of hornets." With this attractive picture before us, we lost no time in going over to the spot, where we found a thriving colony of Bembex spinolæ. On our approach they fell upon us, "desire of blood, and rage, and lust of fight" in their mien, and chased us to a distance, but without inflicting a single wound. This temperance was not due to gentleness of disposition, but to the fact that Bembex is not at all handy with her sting, her body being too large and clumsy to curve and give the lightning stab as other wasps do. With renewed courage we again approached them, more cautiously this time, and soon learned that if we preserved an extremely composed and dignified demeanor our presence on the field would be tolerated.

Bembex, like Philanthus, and some species of Sphex, lives in a sort of semi-social state, a number of individuals occupying the same space of ground, although each one has its separate nest. Bembex, however, differs from these genera and from almost all of the solitary wasps in her habit of feeding her young from day to day, or rather from hour to hour, as long as it remains in the larval state. This difference in her maternal cares as compared with those of other species results in a less numerous progeny. The larva, for a period of two weeks, demands constant attention from the mother, so that a second egg cannot be laid until the first-born has gone into its cocoon, unless, indeed, she feeds two larvæ at once, which does not seem probable. The season of work is ten or twelve weeks, so that Wesenberg is probably correct in allowing only five or six young ones to each mother for the summer.

In watching our wasps we found that the new nests were usually made in the outskirts of the colony, which was thus continually extending its limits. Like many other species, Bembex has great difficulty in deciding just where to dig. Our Sphex made three beginnings before finally settling down. The only Ammophila that we watched from the beginning changed her place after working for ten minutes. P. quinquenotatus often tried

half a dozen places before she was satisfied, and spinolæ is quite as difficult to please.

When, at last, the right place is found, the labor of excavation is carried on vigorously. The mandibles are used for loosening the earth, and for lifting, but the greater part of the work is done with the first pair of legs, the tarsi of which are doubled up while the dirt is swept out with the brush of stiff spiny hairs on the second joint. This attitude gives them a very comical aspect, making them look as if they were sweeping with their elbows. They sometimes lie far over to one side while loosening the earth with their mandibles. While digging, the body is held high by the straightening of the third pair of legs, and the dirt comes out behind in a rapid stream, flying to a distance of three or four inches. Before long the wasp is lost to sight, but every few moments she comes backing out, pushing behind her the dirt that she has displaced below. In about fifteen minutes the nest is ready, and the wasp turns her attention to scattering all the dirt that has been thrown out, sweeping the ground clean so that no sign of her work remains. We have often speculated as to the meaning of the careful and conscientious performance of this part of her task. With the wasps that nest by themselves it is not easy to see what enemy they are providing against in hiding the

entrance to the nest; but the precaution seems still less necessary — even absurd — in the Bembex field, where there is no possibility of concealing the colony, and where the nests are only an inch or two apart, so that an enemy might burrow anywhere with the certainty of finding one. Moreover, the only enemy that we could discover was the parasitic fly, which never attempts to enter when the hole is closed. However, unmoved by our opinion on the subject, spinolæ spends five or six minutes of her precious time in making the neighborhood of her home quite tidy, and then she fills in the mouth of the nest with a little loose earth before going away to catch her fly.

Oxybelus, though she is limited in choice by her small size, can catch a fly in three or four minutes. Bembex is strong enough to take anything that she sees, and she has no preference for one species above another, yet she seldom finds one under twenty or twenty-five minutes. When she comes back nothing of the fly is visible unless it is unusually large, so closely is it held under her body by the second pair of legs. She alights, and scratches away the loose earth at the entrance of the nest with her first legs, and then, as she creeps within, she passes the fly along from the second to the third pair, so that the end of its body, projecting beyond the abdomen of the

wasp, is visible for an instant before it is carried inside. Sometimes she drops the fly behind her, and then, turning around, pulls it in with her mandibles. In other cases, where a longer portion of the tunnel has been filled with earth, the fly is left lying on the ground while the wasp clears the way. This offers a favorable opportunity to parasites, especially as the fly is not placed with regard to its safety, but is dropped anywhere. The dirt that is kicked out sometimes covers it so that when the way is clear the careless proprietor must search it out and clean it off before she can store it away. In one instance, in which we had been opening a nest close by, the tunnel was entirely blocked by the loose earth which we had disturbed, and the wasp worked for ten minutes before she cleared a way to her nest. During part of this time she held the fly, but when she realized that it was going to be a long piece of work she laid it down near by. As the wasp enters she sometimes leaves the hole open behind her, but oftener fills it by pushing up earth from below. When she comes out again she throws in a little dirt, and then begins to circle about the place. She seems not quite easy about the nest, however, returning three or four times to scratch earth over the entrance, before finally taking her departure.

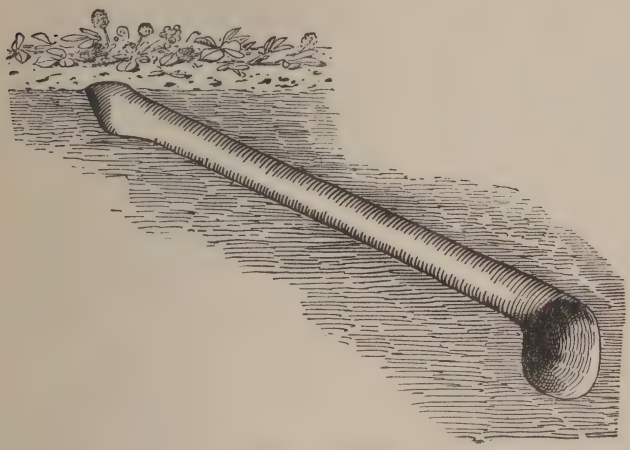
We opened a good many nests in the course of the

summer, and found them all very much alike, much more so than is the case with other species. The entrance tunnel runs in obliquely for from three to five inches below the surface of the ground, and ends in a pocket.

We grow accustomed to marvels, and from our familiarity with other wasps we take as a matter of course the unerring accuracy with which Bembex swoops down upon the exact spot at which the entrance to her nest is hidden. And yet how strange a power it is! There is not the least sign to help her — not a stone, not a blade of grass is to be seen on the field. Our method of marking a nest which we wished to find again was to place tiny pebbles at exactly equal distances from it, one on either side, so that the middle point of the straight line between them gave us the desired spot; and the wasp doubtless uses the same method, only her landmarks are sometimes so infinitesimal that we do not recognize them.

Bouvier finds that when he cuts away the plants around the nest of B. labiatus, clearing a space of twenty-eight or thirty inches square, the wasp is much confused, flying about for a long time before she is able to find her home. He once placed a flat stone over the entrance. The wasp alighted upon it, and after scratching vainly for a while made her way in. The stone was

left in this position for two days, during which time Bembex learned to regard it as a landmark, for upon its being removed to a distance of eight inches she still



NEST OF BEMBEX

followed it upon returning with her fly, and insisted upon finding her nest near it.

An observation of Marchand points to the same conclusion. He says: —

On July seventeenth, 1900, during a short sojourn at Pouliguen, on returning from a hunt after Diptera and Hymenoptera in the cliffs of Caudan, about eleven in the morning, in tropical heat, I paused to take breath near the old mill of Caudan and looked about for a little shade

before continuing my walk to Pen-Château. I had seated myself on the stones of a slope shaded from the sun and was wiping the perspiration from my forehead, when I saw a large wasp arrive directly before me. I instinctively followed it with my eyes; it paused some yards from the mill on the side of the cliff, and began to open a nest which was placed scarcely twenty inches from the foot of a swallow-wort, a rather common plant in the neighborhood of the ruin. She was Bembex rostrata at work at provisioning her nest.

Moved by curiosity, instead of going on to breakfast, I awaited the exit from the nest, which took place in about five minutes. Bembex scratched the sand and took flight from the side of the cliff. How long would she be away? I looked at my watch and arose.

Ought I to go or to wait a little while? I took the latter decision. Out of malice, and without any idea of trying a control experiment to the admirable observations which science owes to the naturalist of Sérignan, of whom I was not thinking at all, I cut close to the sand the stalk of the swallow-wort and planted it a little nearer the mill, moving it about two feet, and being careful to put in place of the plant a little fragment of a bottle which I found in the mill. I seated myself in the shade and waited. Twenty minutes later the wasp dropped straight on to the place where I had cut the plant, that is to say, it deviated from its nest by a distance about equal to the displacement to which I had subjected the swallow-wort. It walked right and left, agitating its antennæ, appearing confused as to the locality.

I followed these goings and comings for two or three minutes. Several times it flew away and then returned, always searching about. Pitying it and desiring, since I was now relieved of the fatigue which the heat had caused me, to go back to breakfast, I took my net and drawing near, made as if to catch it, swinging the pocket rapidly about. It veered away with a quick jerk of the wings. I then took up the swallow-wort, lifting the fragment which marked its original place, and replanted it in the sand.

I again looked at my watch to see whether I could consecrate yet a few more minutes to curiosity without making my kind host, my friend Dr. M^ce^ Rivron, and his wife, who honored me with the charming hospitality of Kursac, wait too long. It was only half past eleven; we usually did not breakfast until about noon; it would take only a quarter of an hour to traverse the distance from the mill of Caudan to the house. I could then, without fear of being chided, dispose of fifteen minutes. This lapse of time would perhaps suffice to show me whether my *bestiole* would this time find the way to her nest without hesitation.

I waited a little; five minutes had not passed when my Bembex, coming like an arrow, alighted on the sand near the plant, still holding the prey which I had noticed when she departed at my chasing her, after her vain attempts to find the entrance to her nest; but this time she did not hunt long. She felt about a little to right and left, but soon turned directly toward the entrance to the tunnel, distant scarcely two inches from the place where she had settled. My Bembex had a memory.

A curious thing about these wasps, and one which shows how much common feeling they have, is that they work in waves, all starting off on their hunting expeditions within a few minutes of each other, and returning together after the chase. At one time all the residents seem to be present, digging their nests, carrying in their booty, dashing at each other, and chasing the parasites with a tremendous amount of humming and swooping about. Then suddenly they are all gone. Nothing remains but multitudes of flies, which keep up a giddy dance over the field, and for ten or fifteen minutes the place seems deserted. Then the wasps begin to return, several coming at a time, and as if by magic the whole scene awakens to life. More than half of the wasps bring nothing home with them, and these fall to robbing their more fortunate companions. Those that are carrying flies must pause a moment, burdened as they are, to scratch away the earth at the entrance to the nest. When unmolested they go in very quickly, but it is just at this point that the marauders fall upon them, displaying an amount of persistence and energy in their attacks that, were it properly directed, might easily enable them to secure flies for themselves.

We once saw a wasp that had been fortunate enough, or perhaps unfortunate enough, to catch an immense

fly, the wings of which stood out on both sides very conspicuously. This made her an especial mark for her unprincipled relatives. Half a dozen of them chased her about, like chickens pursuing one of their number that has found a worm. She circled and settled, and circled and swooped around for five or six minutes, continually pursued and attacked by the robbers, and quite unable to get into her nest. At last, curious to see what she was carrying, we made her drop her load, and secured it for ourselves. We found it to be a horse fly, quite dead, but showing no marks of violence. It was not wasted, for we afterward fed it to one of our wasp nurslings at home.

At another time we saw one wasp attack another that was bringing in a fly. In the struggle that ensued the owner lost her booty, as the two rolled over and over on the ground, and as they parted it was seized by the thief. They clinched again, and rolled on the ground as before, and this time the fly was recovered by the rightful owner. At this point, thinking that perhaps one of the wasps was a male, and that this might be their style of courtship, we seized both of them; whereupon the fly was dropped, and the two wasps turned their attention to attacking us. Both proved to be females. Not only do the Bembecids fight in this way for the possession of their prey — they quarrel even without apparent cause.

We have seen two females digging their nests at a little distance apart, one of which was repeatedly attacked by the other, although she did nothing to provoke the aggressor. They are certainly very unneighborly, and have no idea of living in harmony. When flying in a threatening manner, either at us or at each other, they have a way of wagging their abdomens violently from side to side in a way well calculated to inspire terror.

In warm sunny weather spinolæ works industriously through the middle of the day, and seems determined to provide abundantly, not only for her own offspring, but for any unbidden guests that it may be her fate to care for. She never works more than four or five hours a day, however, and in unfavorable weather she does not work at all. On going over to the island one cloudy morning to spend some hours in watching the Bembex activities, we found the spot quiet and lifeless. No one seeing it for the first time would have dreamed of the multitudes of living creatures beneath his feet. The nests seemed to be all closed, but on peering curiously about we found one on sloping ground, in the suburbs of the colony, of which the door was open. Just within was the proprietor gazing out on the landscape, as she is shown in the illustration. She seemed to be leaning on her elbows, and her face, enlivened by two great goggle eyes, had an

irresistibly comical aspect. With the exception of the omnipresent flies, this wasp was the only sign of life about the place. Even in good weather, and in working

BEMBEX SPINOLÆ LOOKING OUT OF NEST

hours, the wasps sometimes rest, for we have seen them go in empty-handed, closing the door behind them, to remain for half an hour at a time.

There is one thought that must strike even a casual observer at the sight of the hordes of parasites that hover over a Bembex colony: —

"The buzzing flies, a persevering train,
Incessant swarm, and chased return again."

Why do not these wasps, fly-catchers as they are by profession, kill the worthless wretches that infest their homes, thriving abundantly on the fruits of their labor, a continual menace to the life and safety of their offspring? To the uninitiated it would seem that these flies might serve as food for the wasp larvæ quite as well as any of the dozen species that they actually take; but even if the wasp-mother believes that they possess indigestible qualities, it would be much less trouble to kill them and throw them away than to be perpetually chasing them to a little distance only to see them return as soon as she gives her attention to anything else. Whatever the reason for it may be, the relation between the wasps and the flies is certainly most curious and puzzling. Fabre's explanation is that since this miserable little fly has its own part to play in nature, Bembex must respect it, thus preserving harmony in the world of living things. The idea is perfectly in accord with his own theories, but we find ourselves quite unable to accept it.

There can be no doubt that the parasites are a grave danger to Bembex. She suffers from them far more than any other wasp that we are familiar with, her mode of feeding the young rendering her peculiarly susceptible

to their attacks. Of the ten or twelve nests that we opened only one was free from them, the others containing from two to five lively maggots nearly as large as the wasp larvæ, which were sharing the food brought in by the mother. Fabre, who has studied the question thoroughly, has found as many as ten parasitic larvæ in one nest. He has also noticed that where the parasites are most numerous the wasp-larva is proportionately small and emaciated, reaching only one half or one third of its normal size. When it attempts to spin its cocoon it has not strength enough to do so, and thus perishes miserably among the pupæ of the interlopers, which have the advantage of developing more rapidly. He has proved, by experiments upon nests transported to his study, that although the invaders preserve friendly relations with the rightful owner of the nest so long as food is abundant, they nevertheless, at the first suggestion of scarcity, fall upon the wasp larva and ruthlessly devour it. This "black action" he has seen with his own eyes. In view of this base ingratitude, we are more than ever impressed with the troubles of the poor Bembex mother, as she tries to feed a dozen mouths where she has bargained for only one.

We several times saw a fly follow a wasp into her nest, remaining within for half a minute, and it is probable

that they go in to lay their eggs. According to Fabre, it is the habit of the flies that are parasitic upon the half-dozen species of Bembex that he has studied to seize the moment at which the fly projects from under the abdomen of the wasp as she enters the nest; and he has even known them to lay two or three eggs on one fly in the instant of time that its body was exposed.

Fabre took a partly grown Bembex larva from the nest, where it was surrounded by the remains of twenty flies. He fed it generously, and it ate sixty-two more, making a total of eighty-two in the eight days that passed before the spinning of the cocoon. Our experiments in this line gave similar results. We took charge of a partly grown larva on the afternoon of August tenth, and between that date and August fifteenth, when it spun its cocoon, it ate forty-two house flies besides a big Tabanus.

Fabre thinks that under natural conditions the mother does not give the larva all it can eat at one time, but provides it with what she considers a reasonable amount of food, and keeps anything that she catches beyond this out of its reach. He draws his conclusion from the fact that he has found several flies in the tunnel leading to the nest, while the larva had as many more close to it. It would certainly be convenient for Bembex to have a

reserve of this kind in case of rainy weather, but the forethought implied in such an action seems to require a higher degree of intelligence than can be claimed for her.

In one nest we found a single fly with a long cylindrical egg attached to the left side of the thorax just at the origin of the third leg. In another, which we had seen made and provisioned, we found, six days later, a larva which we judged to be four days old. Assuming that the egg was laid on the first day, it must have taken it about two days to hatch. Other nests gave us larvæ in all stages of development, surrounded by the remains of Diptera, among which Syrphus, Tabanus, and Musca were represented.

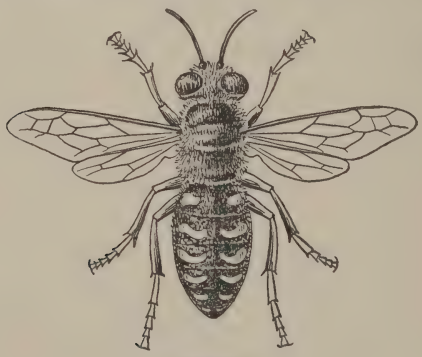
In regard to the condition of the flies captured by Bembex, we have never seen the crushing of the thorax, which is noted by both Wesenberg and Fabre. Indeed, the flies that we found were not always dead, since in two instances they responded readily to stimulation. Similar results have been obtained by Mr. S. W. Dunning of Hartford, Connecticut.

Twice we have seen our spinolæ, as she was bringing home her prey, alight near the nest and sting it as it was held with the second pair of legs. We could see the process distinctly, since she is slow and clumsy, and, in one

instance, had difficulty in reaching the fly, falling over to one side in an awkward manner. It is probable, then, that this is a habit with the wasp, but that the sting is usually given at the place of capture.

We opened a number of Bembex nests, but succeeded in raising only one larva, which we took when it was half grown. This one, during the five days that passed before it spun the cocoon, ate forty-three flies.

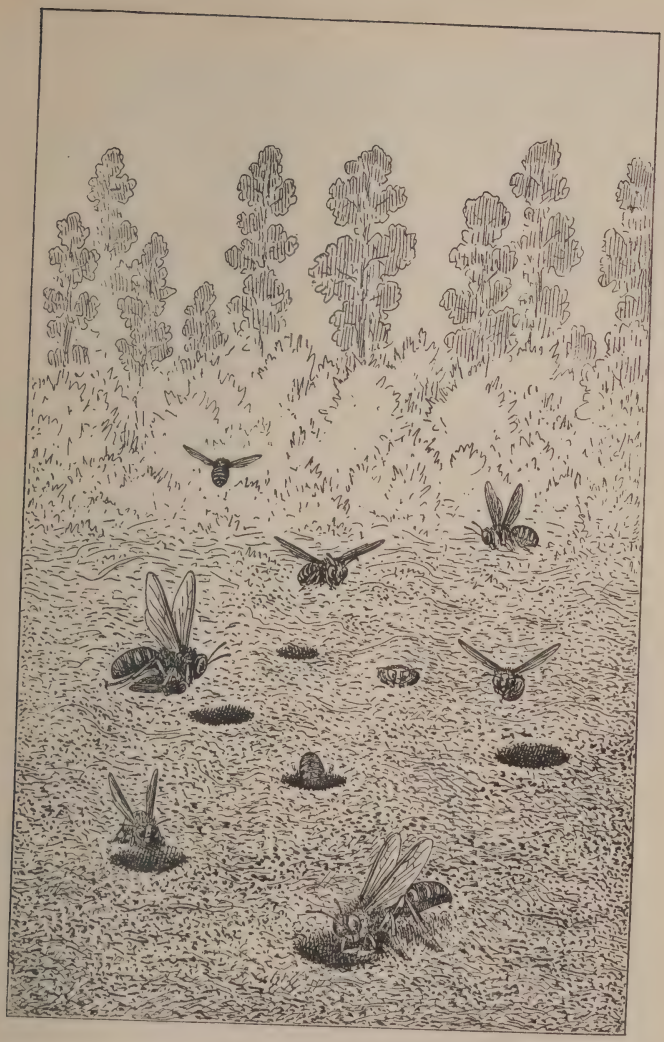
Mr. Bates has some notes on Monedula signata, which takes nothing but flies, and even confines itself to a single species, although it must sometimes go half a mile away



BEMBEX

to find it. This reminds us of Pompilus quinquenotatus, which never takes anything but Epeira strix.

A considerable contribution to our knowledge of the genus Bembex has been made in the paper by Wesen-



A CORNER OF THE BEMBEX COLONY

berg (written in Danish) which has already been referred to. This paper deals with Bembex rostrata. It was translated for Mr. Ashmead by Mr. Martin Linell.

It seems that rostrata makes its nest in solid sand, covering it up with loose sand, and usually, also, with a little flat stone, to prevent parasites from entering. The cell measures one cubic inch, the entrance tunnel being one and one half centimeters long, and arcuate. A cell contains four or five fresh flies (Lucilia, Eristalis, etc.), and torn-off wings, sucked-out thoraces, and in the middle of these, a big flat larva.

When the larva is hatched the mother brings more and more flies, the flies being larger and larger as it grows. This adjustment of the size of the fly to the growth of the larva has also been noted by Fabre.

Wesenberg says that fifty Bembecids will nest on a spot as big as a room during a period of three months. The time required for the development of the larva is two weeks, this giving five or six young ones for the season. He queries, "Does each female have more than one nest? and if so, how can she remember them?" To determine this point we marked six wasps by touching them with differently colored paints, putting near their nests pebbles painted to correspond with the owners, and then watched them closely for three hours.

During this time the red wasp returned regularly to the red nest, the blue to the blue, and so on. They were watched for an hour and a half on the following day with the same result, so that it seems quite certain that spinolæ has only one nest at a time. To feed two larvæ at once, with interlopers thrown in, would be a heavier task than the most determined industry could accomplish.

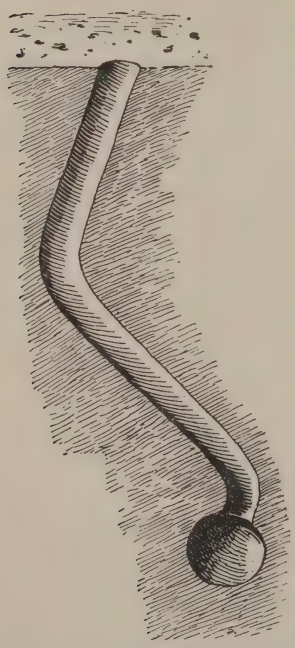
Chapter VII

THE BURROWERS

DUFOUR, in describing the fearful ravages of Cerceris ornata among the bees, says that the wasps of this genus are among other insects what eagles and hawks are among birds. While this characterization does not seem to fit the American species, it is certainly true that the genus stands out as one of those in which the distinctive peculiarities are strongly marked. They might be considered the aristocrats in the world of wasps, their habits of reposeful meditation and their calm, unhurried ways being far removed from the nervous manners of the Pompilidæ or the noisy, tumultuous life of Bembex. Their intelligence is shown by their reluctance to betray their nests, and by their uneasiness at any slight change in the objects that surround them. It is not necessary to attempt to catch them or to make threatening gestures, in order to arouse their sense of danger. If you are sitting quietly by a nest when the wasp opens her door in the morning she will notice you at once, and will probably drop out of sight as though

she resented your intrusion into her privacy. After a little she will come up again and will learn to tolerate you, but at the least movement on your part, almost at the winking of an eyelid, she will disappear.

Our four representatives of this genus all prey upon beetles that are injurious to vegetation, and therefore deserve the gratitude of agriculturists. Nigrescens, with her pale grayish bands, is a very trying wasp to deal with. We had seen her flying about in the garden for weeks before we succeeded in tracking her home, and when we did succeed she was so late about getting up in the morning, stayed away from home so many hours at a time, and went to bed so early in the afternoon, that we were not well repaid for watching her nest all day. Fumipennis, large and handsome, with a broad yellow band at the front of the abdomen, is another wasp that has no



NEST OF CERCERIS NIGRESCENS

regard for the convenience of the people who are watching her. You may sit by her big open hole for hours without seeing her, and when she comes she drops in so suddenly that, unless you are very much on your guard, you are not sure even then what she is. Clypeata and deserta are better subjects for study.

The nests of our species are all deep, tortuous, and very difficult to excavate. We have never succeeded in finding their pockets; and yet, for various reasons, we feel perfectly certain that all of them are like C. ornata in provisioning, successively, a number of cells which lead out of the main gallery.

CERCERIS CLYPEATA

When one of these cells is filled with food, and the egg deposited, it is probably closed up, and thus separated from the runway. From our experience late in the season with the nests of another wasp, we are inclined to think that we made a mistake in looking for pockets at the lower end of the tunnel. Had we searched higher up, at the point of the curve, we might have found them, the lower part of the gallery probably being

designed merely for a dwelling-place for the mother of the family.

But although we did not get distinct pockets, there was, in at least one nest, a supply of food that would have far exceeded the wants of a single larva. We did not succeed in finding eggs on different groups of beetles; but from a nest into which the wasp was still carrying food we took a half-grown larva which was identified as being hers. The fact, too, that a wasp occupies a nest for so long a time as ten days or two weeks points to the conclusion that she uses it for a number of eggs which are laid at intervals.

Cerceris digs her nest, deep as it is, all at once. In this she is a contrast to her near relatives of the genus Philanthus, who busy themselves for an hour or so every morning with fresh excavations.

On the eighth of July the weather was so warm and bright that we went down to the garden at half past eight o'clock, knowing that it was rather early, but hoping that the hot sunshine would tempt the wasps to industry. We had walked up and down several times, when suddenly, right in the pathway, a nest appeared. A great quantity of loose earth had been taken out and heaped up, probably on the preceding day, and in the midst of this a little hole had been opened since we

passed before. The place looked so promising that we sat down to watch it, and a few minutes later we were rewarded by a glimpse of some antennæ down the gallery, and then a little face with yellow markings appeared but quickly vanished. Now followed a very coquettish performance. The wasp came slowly creeping up again and again, only to drop out of sight as soon as she had reached the opening. After a time she grew bolder, and sat in her doorway, twitching her head this way and that in a very expressive manner, as though she were planning the work of the day; but it was plain that although she was up early, business cares were not weighing heavily upon her mind, for forty minutes passed before she came out of the nest, and after making three or four circles about the spot, flew away.

How much livelier and more interesting it would have been if we could have followed her! We tried to guess at what she was doing, and imagined her hunting industriously. After fifteen or twenty minutes it seemed to us that she must have caught something, and that she was surely returning. Most probably she was not working at all, but was breakfasting leisurely and exchanging compliments with her neighbors; for when she did come home after keeping us waiting for an hour and a half, she brought nothing with her, and seemed

quite unconscious of the fact that greater things had been expected of her.

We had placed a stone upon a dead leaf near by, to mark the neighborhood of the nest, thinking that even a Cerceris could not object to so simple an arrangement of natural objects; but our wasp noticed it at once, and evidently with much suspicion and disapproval. She began by circling several times just above it. Then she alighted on it and examined it carefully, walking over it, and creeping underneath, perhaps to see whether it in any way menaced the safety of her nest, perhaps as the completion of a locality study made the day before. She then rose on her wings, and after a little more circling, dropped suddenly into her hole.

So far we had not been getting on very rapidly, but from this time things took a turn. Cerceris is never in a hurry, and yet she may be relied upon to do a certain amount of work every day. The one that we were now watching had probably come back for a final look at her newly made nest before beginning to provision it; for she soon reappeared, and this time really went to work, since in forty minutes she brought home a beetle which she carried by the snout, venter up, in her mandibles, supporting it with the second pair of legs while flying. She was much annoyed at our presence, and circled

about as before. Twice she alighted near by, and walked around for a few minutes, and when she did this all her feet came down to the ground, the beetle being allowed to hang loosely. At last she made the best of a bad matter, and went in. The rest of the morning was occupied with hunting, the capture of each beetle taking about forty-five minutes. Every time that she came home she spent fifteen or twenty minutes in the nest.

This species soon became very common, and for two weeks scarcely a morning passed without our finding at least one newly-made nest. The study of clypeata, however, consumes a great deal of time. For example, we found, one morning, two nests within six inches of each other. It turned out afterward that these were inhabited by two different wasps; but at the moment we supposed that one of them had been dug and deserted and then a second one made, and wishing to know which one was occupied we resolved to watch and see. After waiting for three hours we saw one wasp returning; but upon noticing us she veered off and began to circle about. She was heavily laden, and her burden, instead of being supported by the second pair of legs, as is sometimes the case, hung down under the thorax and abdomen. After a moment she alighted on a plant near by, and seemed to consider the situation, then circled a little more, and

flew away, remaining out of sight for fifteen minutes, then another return, more circlings and hesitations. She seemed to feel the weight of the beetle now, and alighted frequently on the ground and walked about; yet she would not go in, so reluctant was she to betray her nest. In this way she kept us waiting for a whole hour, although we were not very near to her, and were as still as statues. At last we retreated, and stood as far back as we could and still keep the hole in view. She now came closer, and, after hanging poised on her wings for a moment, dropped into her nest.

We once found a nest of this species in process of construction. A large heap of fresh earth had been pushed out, which entirely covered the spot; but at intervals there were upheavals from below which betrayed the presence of the wasp. When we saw it first it was half past eight o'clock, and we judged, from what had been accomplished, that she must have been at work at least an hour. It was half past nine before the excavation was complete. We had not been certain, up to this time, as to what we were watching; but now we had the pleasure of seeing her open her doorway from below and stand in the entrance while she washed her face with her fore feet, like a cat. When they rest at the mouth of the hole the first legs, which are yellow, are bowed in a semi-

circle on each side of the yellow face, the distal joints being bent up so that the wasps seem to be standing on their elbows. This attitude, which is often seen in Bembex spinolæ, gives them a delightfully amusing, bow-legged appearance. They usually open their nests in the morning at about nine o'clock, — a little earlier or later according to the time at which the sun strikes the spot. Then they spend from forty minutes to an hour in taking a survey, the least movement on the part of a watcher causing them to drop out of sight as if the earth had given way beneath them. Sometimes there is a little way-station an inch or two within the tunnel, and the wasp falls back only to this point, and here she may be seen, if one peeps in cautiously, either quietly awaiting the retreat of the intruder, or, perhaps, performing her toilet in a leisurely and elegant manner.

Whenever she leaves her nest she makes three or four rapid circles around the spot to freshen her memory of the locality. The most thorough study that we saw made by clypeata was in the case of the wasp mentioned before, that was so long in carrying her beetle in because of our being on the ground. When she finally did go in she stayed only an instant — just long enough to deposit her load — and then came out and spent a long time in an investigation of all the surrounding objects,

flying in and out among the plants, now high, now low, and circling again and again around the spot. It looked as though she had been puzzled and disturbed by the presence of unaccustomed things. As soon as the survey was over she went inside and closed the door, as though its object had been not so much to strengthen her memory as to correct former impressions.

The work of bringing in beetles goes on very irregularly, and as a rule not more than two or three are stored in the course of a day. It is not unusual for clypeata to spend three or four hours away from home and then come back without anything; and often, even in the middle of the day, she passes an hour or two in the seclusion of her nest. We had several nests under observation for a week at a time without ever once seeing the owners, although they were evidently occupied, since they were sometimes open and sometimes closed. The outer entrance is always left open when the wasp goes away, although possibly access to the pockets may be barred below; but when she enters she closes the door unless she means to come out again at once. The closing is sometimes effected by pushing the earth up backwards, with the end of the abdomen; but the hole is rather too large for this method, and more frequently the wasp comes up head first, carrying a load of earth in her front

legs. This is placed just within and to one side of the entrance, and then more armfuls are brought up, until, after two or three trips, the opening is entirely filled.

We once captured the wasp in a bottle, as she returned, loaded, to the nest. She dropped the beetle, but soon picked it up again and stung it vigorously, *with intention*, as the French say, first under the neck, and then further back, behind the first pair of legs. After this it was dropped while the wasp fluttered about for a few minutes, but it was then picked up again, and stung as before. We both saw this operation repeated in exactly the same way, four different times, with intervals of five or six minutes between.

In a nest which we excavated after watching it for nine days, we found nothing until we had gone six inches down, and at this point the tunnel was lost; but mixed with the crumbly earth that we took out of the hole, we found eight beetles and a half-grown larva of clypeata. The destruction of this nest was accomplished one morning, and when we came back to the spot twenty-four hours later we found that a new one had been made close by, doubtless by the same individual. We had expected to find her bringing beetles and dropping them foolishly on the ground like Paul Marchal's Cerceris ornata, and were gratified that she showed an advance

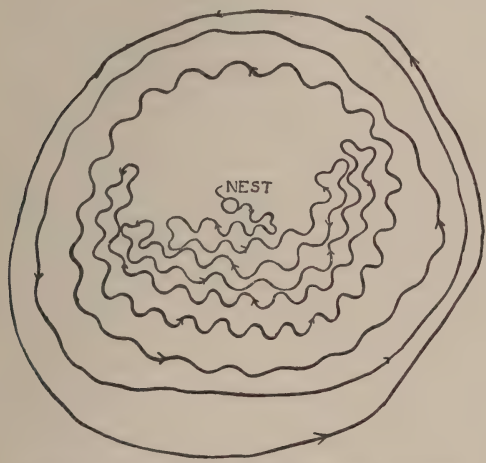
in intelligence over that species, although to be sure she would have been still wiser had she chosen an entirely new neighborhood. Another individual was so much disturbed by our scrutiny that she dropped her beetle at the entrance to her nest. She did not pick it up again and utilize it, although it lay for three days in the dust at the threshold.

As to the condition of the beetles stored by clypeata: in the first nest that we opened we found eight, seven of which were dead, while the eighth, which we had just seen stung several times, was alive, but died on the following day. The second nest gave us five beetles, all of them dead and dry. In the other nests that we opened we found nothing, though we knew that the beetles were there had we only been skillful enough to discover them.

Of Cerceris deserta, which closely resembles clypeata, but appears later in the season, we had only a single example. We chanced to see her dropping into a crevice among some lumps of earth, and at first could scarcely believe that this was the dwelling-place of a wasp, as there was nothing whatever about it to indicate a nest; and even after we had removed the rough pieces of earth above, we could see nothing of the loose material that must have been carried out.

She was much like clypeata in her manners, with the

same habit of surveying the world from her doorway, and manifesting the same annoyance at our presence when she was returning to the nest; but she carried in more beetles in the course of the day and worked much



CERCERIS DESERTA: LOCALITY STUDY BEFORE LEAVING NEST

more rapidly. Between nine and eleven o'clock one morning she brought in five loads, and some of the journeys occupied only ten minutes.

The first time that she found us sitting by her nest she circled about for nearly an hour, seeming unable to make up her mind to enter. At length we withdrew a little way, but still her suspicions were not entirely

allayed; and after a further study of the situation she dropped, not into her own nest, but into a large cricket hole near by. Taken aback by this manœuvre, and thinking that perhaps we had a second individual to deal with, we stealthily approached, and peering in, could see the cricket inside, the wasp having slipped beyond. It did not seem possible that the little creature could be endeavoring to deceive us, and yet what other explanation could be offered for her conduct? We again took up our distant position, and after ten minutes more had the satisfaction of seeing the wasp slip out of the false nest and drop instantly into the true one. After a little she became quite accustomed to us, and entered her nest without the least delay.

The prey of deserta is held in the mandibles, and while we were watching her she did not support it with the second legs, even when flying.

Philanthus punctatus is a pretty little yellow-banded species much resembling Cerceris in appearance. The nest consists of a main gallery with pockets leading from it, each pocket being stored with one egg and enough bees to nourish a single larva. When the wasps emerge from the cocoon they find themselves in the company of their nearest relatives and in possession of a dwelling-place, and they all live together for a time before starting

out independently to seek their fortunes. On the fifth of August we discovered on the island a happy family of this kind, consisting of three brothers and four sisters, the females, with their bright yellow faces and mandibles, being handsomer than the males. They seemed to be on the most amicable terms with each other, their only trouble being that while they were all fond of looking out, the doorway was too small to hold more than one at a time. The nest was opened in the morning at about nine o'clock, and during the next thirty or forty minutes their comical little faces would appear, one after another, each wasp enjoying the view for a few minutes with many twitchings of the head, and then retreating to make way for another, perhaps in response to some hint from behind. Then one by one they would come out, circle about the spot, and depart, sometimes leaving one of their number to keep house all day alone. They usually left the hole open; but when there was a wasp within, it was soon closed from below. During this playtime period they did not return until they were ready to settle down for the night, the first one coming home at half after two or three o'clock, and the others arriving at intervals, none of them staying out later than five. Most commonly they found the right spot without trouble, scratched open the hole, and then either closed

it behind them or stood waiting in the doorway for the next arrival; but occasionally they had difficulty in locating the nest, and worked at two or three different places before finding it.

We kept these wasps under close observation, often watching the nest from the moment it was opened in the morning until it was closed at night. On the twelfth of August, a week from the time that we first saw them, one of the females felt the responsibilities of life settling down upon her. At half after four in the afternoon she began to enlarge the nest, and worked with a great deal of energy for forty minutes. After a long disappearance within the hole she would come up backwards, kicking behind her a quantity of earth which was not only taken outside, but was then spread out far and wide. She worked with the front pair of legs, which were curved inward, after the manner of Bembex; and when a pebble or some such object came in her way she either dragged it to a distance with her mandibles or pushed it before her with her head in a way quite peculiar to herself. In distributing the earth that was taken out, she went five and one half inches from the nest — a distance which is much greater than is common among wasps, but which accords well with the habits of punctatus, since she continues the work of excavation from day to day.

On August thirteenth, at half after eight in the morning, we found that a second female, perhaps inspired by the example of her sister, had made a new nest within two inches of the first one, and had flown away, leaving it open. Presently the other wasps began to appear, one after the other, in their doorway. Two of the males flew away, and one of the females, doubtless the one that we had seen digging the night before, began to work afresh at making the nest larger. Probably she was excavating a pocket for the reception of an egg, and the amount of labor required was ernormously increased by the great length (about twenty-two inches) of the main gallery by which the displaced earth must be carried out. She worked for an hour, and in spreading the dirt about, inadvertently filled in the opening of the second nest. At length she flew away.

PHILANTHUS PUNCTATUS

At ten o'clock a female arrived carrying a bee, and tried to find nest No. 2. She came to the wrong place, and worked about, here and there, for some minutes, holding the bee under the thorax, clasped by the second

pair of legs. Being unsuccessful, she dropped her burden, and flew away for a few minutes. While she was gone we removed a leaf that had fallen over her nest, and on her return she at once descended upon the right spot, and began to scratch open the entrance, the bee being kicked backward with the rejected earth. When the way was clear, however, she picked it up, brought it toward the hole, dropped it, ran in and out, brought it nearer, ran in again, and turning around in the tunnel, seized the bee in her mandibles and pulled it down. This performance was due to the accidental obstruction of the gallery, for we afterward found that punctatus ordinarily flies directly into her nest, or, when it is closed, pauses on the wing to scratch an opening with the first legs. The bee is pushed backward a little as she goes in, but does not often project from under her abdomen.

At fifteen minutes after ten the worker from nest No. 1 brought in a bee, and from that time the two worked industriously. They showed some individuality in their ways, for No. 2 always closed her door when she went away, and never circled at all, while No. 1 invariably circled before leaving, and always left her nest open. To be sure, there was a female left on guard, so that perhaps she did not feel the need of caution.

Our wasps had not far to go for their victims. Forty feet away, on the eastern side of the island, was a steep declivity, and here, in the soft crumbly soil, was a great Halictus settlement. No prettier sight can be imagined than is presented by this colony on every sunny summer day. The whole bank is riddled with nests, and at the entrance of each stands a female bee, her tiny head exactly filling the opening. The bees are constantly arriving, laden with pollen, whereupon the sentinels politely back inward to make way for them. Into this scene of contented industry descends the ravaging Philanthus, taking guards and workers alike.

On the afternoon of the fourteenth of August our two wasps were in the full tide of affairs. No. 1 took in eleven bees within two hours, but her record was somewhat confused, as two other females were going in and out at the same time. We felt sure that neither of these was hunting, but one of them shared in the labor of the nest by helping with the work of excavation.

No. 2, however, was alone, so that we could keep a definite account of her comings and goings. We watched her from half past one until five, at which hour she came home without a load, and at once closed the nest for the night, after having stored thirteen bees in three hours and nine minutes. In some cases the capture of

the bee occupied only one, two, or three minutes, while at other times she was gone much longer. At each return she stayed only an instant — just long enough to deposit the bee — inside the nest, and then spent a minute in carefully closing the hole. The wasps that were going in and out of nest No. 1 sometimes closed it when they went away, but this was done in an untidy fashion, quite different from the nicety and precision of No. 2.

At half after five o'clock the wasp that had been digging for some little time at nest No. 1 flew to nest No. 2, opened it, and attempted to enter, but was quickly driven out by the owner. She then dug a little in several other places, finally returning to sleep in the family home. On the next day we found that No. 2 was tolerating in her nest one of the females that had not yet begun to hunt, but whether it was the one she had rejected the night before or the fourth member of the sisterhood, we could not tell. On the eighteenth, three days later, the wasp had left this temporary home and made a nest for herself four feet away on the hillside. The males were still living in the first nest with two females.

When the weather was cold and cloudy punctatus remained closely housed within the nest, or, at most, came out to do an hour's digging, and then disappeared. The warmer the weather, and the more brilliant the

sunshine, the more rapidly they worked. When leaving the nest they would often creep out and walk around it three or four times before rising on their wings, and even then would sometimes alight once or twice before flying away. The males, especially, liked to stand about for a time, watching their more industrious sisters at their work. The females usually began the day with digging, and frequently closed it, toward night, in the same way.

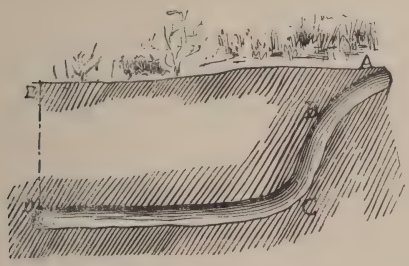
In order to see the method of stinging, we at one time provided ourselves with a number of bees, and putting one of them into a bottle, introduced a wasp. She seized it almost immediately, with great vigor, and stung it once, under the neck, and then dragged it up and down the bottle by one antenna which was held in the mandibles. After a moment she shifted it and held it with the second legs in the usual way. We now put in another bee, which she also caught, stung in the same place, and then dropped without relaxing her hold of the first one. As she seemed to have nothing further to show us we released her, and after circling a little she took into her nest the bee that she was carrying.

In our next experiment we used a larger glass, thinking that with more space we might see malaxation. The instant that the wasp was introduced she grasped the

bee with one rapid powerful motion, and stung it just under the neck as before. Then holding it with the second legs she began to fly about in the glass. We now introduced another bee, whereupon the first one was relinquished, and the second was treated in exactly the same way. The stinging was the beginning and the end of the operation, and when we released her she at once took the bee into the nest. There was no malaxation outside, and certainly there was none within, as was shown by the rapidity with which the wasps issued from the nest after storing the bees. We were successful in getting the wasps to sting only when we tried the experiment with those that were hunting. When those that had not yet begun to store their nests were put into the glass they paid no attention to the bees.

The victim of the sting of punctatus is killed at once. Life is extinct from the instant that the stroke is given. This is true also of the honey-bee that is the victim of Fabre's Philanthus apivorus; but the explanation that he gives of the action of his wasp in thus dealing sudden death instead of paralyzing its foe — that the honey must be sucked out of the bee before it can be safely used as food for the larva — does not hold good in our case, since the honey that Halictus carries to mix with the pollen upon which her offspring are fed, is not removed.

As time went on we found on the island two other Philanthus colonies, although that is rather too large a word to apply to them, since one consisted of four nests and the other of only two. When we came to excavate the nests of this species we were greatly astonished at the length of the gallery, and not until then did we properly appreciate the industry of these little wasps. It is no small undertaking to follow one of their tunnels for



NEST OF PHILANTHUS PUNCTATUS
A–B, 3½ inches; B–C, 5 inches; C–D, 14 inches; D–E, 8 inches

twenty-two inches, even when, as in this case, the greater part of it is parallel to the surface of the ground. We did not find distinct pockets, as the soil was very crumbly and fell in as we worked, but we came upon clumps of bees an inch or so to one side of the gallery and about three inches apart, with larvæ in different stages of development. In one nest we found twenty-six bees in

two clumps, some of them half-eaten, and some of them fresh, but all quite dead. We have no doubt that punctatus completely provisions one pocket and closes the opening from it into the gallery, before she starts another, making a series of six or eight independent cells. The provision for one larva is probably twelve or fourteen bees, the capture of which, in good weather, would be a fair day's work.

That the males do not always stay on in their ancestral home is shown by an observation that we made on the only occasion that we ever saw this species in our garden. Nothing was stirring at half past three o'clock in the afternoon, and we had given up work and started for home, when, in going up an inclined part of the field, we noticed something in motion within a ragged-edged hole which ran obliquely into the ground. It seemed strange that a wasp should be beginning its nest at so late an hour; but a wasp it was, as we could plainly see when we took an attitude sufficiently humble. It was loosening the earth with its mandibles, and then pushing it backward with its hind legs and abdomen. We had scarcely settled down to watching it when a second one of the same species appeared, and with a good deal of fuss and flutter began to dig its hole close by. The spot chosen by this second one proved unsatisfactory, and

another beginning was made in a new place. Again something was wrong, nor was a third choice any better. At last, however, the work was started in earnest, and might have been carried to a conclusion if we had not caught the little creature to satisfy a suspicion that had been growing in our minds. Yes, we were right. The worker was not a female making a nest for the rearing of her young, but a male punctatus, preparing a shelter for the night.

In the mean time the first wasp had pushed back such a quantity of earth that the hole was entirely closed, but every few minutes he came backing out to clear the way. At the end of half an hour all became quiet. The door remained closed, and doubtless the wasp was fast asleep. Putting a blade of grass and then an inverted tumbler over the nest, we left him for the night.

On removing the glass at half past seven the next morning, we found the nest open but the wasp not visible. At half past eight the head appeared just inside the hole, the long antennæ twitching now to this side, now to that, as if an inspection were being made. Soon the head came out. The wasp stood for some minutes making a survey, looking to right and left with lively jerks of the body. Then, apparently concluding that the day was not far enough advanced, he came out, whirled

around, and ran head-first into the nest. He probably took another nap, for all was quiet until just before ten o'clock, when the antennæ appeared again. The survey was taken as before, first from within and then with the head in view. At last he flew out, and making three circles, each one wider than the last, about the place, flew away. He stayed out all day, and had not returned at half past three in the afternoon; but on going down at half past four we found that he had gone in and closed the door from below.

It is clear, then, that these males do not construct a new lodging every night, but return to the same spot to sleep. Other wasps creep into crevices. We have often found them, in the morning, in the holes of the posts of our cottage porch; but we are glad to be able to put it down to the credit of one male that he has sufficient foresight and industry to provide a sleeping-place, and sufficient intelligence to return to the spot when the declining sun warns him that evening is approaching.

While punctatus was in the height of its activity we found another species, P. ventilabris, taking bees of several genera and species into a ground nest. She also carried her prey with her second pair of legs, and whenever she left her nest she closed the door. She was a shy little thing, and did not approve of our interest in

her. At one time, being startled by some movement on our part, she dropped her load and flew away. We placed the bee upon the closed nest, and when she came back with another, she paused and looked at it, took in the one she was carrying, and then returned for number one. This was placed on the threshold while she entered and turned around, and was then pulled in. Some wasps, notably C. ornata and our little tornado, refuse to take in their prey, even if they have caught it themselves, excepting in a regular succession of events; and thus the more reasonable conduct of ventilabris gains in interest.

To the west of Milwaukee, across the valley of the Menominee, rises a sandy hilltop which is a little insect kingdom by itself. Ants of course abound, and the gentle little solitary bees, with their loads of pollen, may be seen everywhere, seeming to melt into the ground, so quickly and quietly do they open their burrows. Here Oxybelus plys her trade of fly-catching, and graceful Ammophila dances with her shadow over the sunny ground, while Cerceris rests in her doorway with an air of leisurely superiority to the vulgar cares of life; and here, one day in early July, a sudden access of energy seemed to strike Aphilanthops frigidus, a wasp which we had found a year before taking in the wingless queens of ants. All at once they were digging everywhere, biting

and scratching with great energy, and soon disappearing in the depths of their sandy tunnels. So deep is their primary gallery that even in this easy medium it takes them the best part of a day to get it ready for storing; but once finished it doubtless serves as a home through the season. It has at the entrance a little cup-shaped vestibule where the wasp drops the ant as she enters, running out of sight herself, and then, after she has turned around, coming back to pull it within. This nest is a very difficult one to excavate neatly, as the sand falls at the slightest touch.

A day or two after we had seen frigidus making her residential arrangements, we found twenty-five or thirty within a few feet of each other, working with great ardor at carrying in queens, the doors being left closed or open according to individual judgment. The steadiest workers brought one every forty minutes, scarcely pausing inside the nest, but others made long stays within, leaving the door closed. The ants were carried under the body with all the legs folded around them, but they were heavy things, and were often dropped as the wasp flew across the field, giving opportunities for robbery that were promptly taken advantage of. We picked up one of these ants and placed it in the doorway of a wasp that had just gone in. She came up twice, looked at it,

APHILANTHOPS GATHERING ANTS

and backed down again; but the third time she first touched it, then seized it and took it below. From another wasp that was just entering we took the ant she had dropped and moved it half an inch away. When she had turned and come up for it, she seemed surprised, came out and looked about, found it and dropped it in the doorway, going in herself to turn around as before. We seized this chance to move it again, and again she came out, found it, took it back, and dropped it. This was repeated five times, but when she took it in for the sixth time, after dropping it, she whirled around and picked it up so quickly that our malice was foiled.

We were puzzled by the actions of a wasp that approached her nest again and again, but always circled away without entering, until looking closely we saw that she was pursued by two tiny flies. When she alighted and walked about awhile with her ant tucked under the third leg on one side, the flies alighted also and walked about behind her. In the end she evaded them by a sudden drop into her hole.

A wasp now came circling along with an ant in her grasp, and settled down between two small weeds that grew about four inches apart. She stood quiet a moment and then began to dig, but had evidently struck the wrong spot, for after a moment she moved and tried

another place. Not finding the entrance, she rose and flew close under one of the plants and began to scratch again, but still in vain. For ten minutes she persisted, keeping within a few inches of the spot, and holding on to the ant all the time, although it was dreadfully in her way as she walked about. Then she dropped it and began to dig more vigorously, dividing her attention between the two spots she had attempted at first. She seemed troubled at having to leave the ant, and often picked it up and tried to hold it while she worked. Once in a while she would take it with her, and after circling about the spot would disappear, but in a few minutes she would return. It seemed to us that two little plants growing near together must have been her landmarks, and that probably she had been deceived by the likeness that those before us bore to the ones near her nest. Again and again she seemed to hesitate and think the matter over, but gradually one of the holes absorbed her more and more. At the end of an hour she was out of sight in it, and had carried her ant down, although she was still kicking out sand. It was evident that her memory had played her false, and that she had either covered her hole so neatly that she could not find the spot herself, or had missed the place entirely. She had accommodated herself to circumstances pretty well,

although she ought to have realized earlier that it would be easier to dig one nest than two.

We now tried to excavate a nest, but could not follow the tunnel, although we found clumps of ants at different levels, some with larvæ feeding on them. The deepest were eighteen inches down. Hoping to secure a guide, we borrowed an ant as it was dropped in the doorway and tied a thread to it. The wasp pulled it in and took it part way down with this attachment; but before any great depth was reached, the thread was seemingly bitten off, as we found the free end without the ant. A second attempt brought no better results.

So long as we were quiet the wasps did not notice us, but after being disturbed they became shy and circled about a good deal before entering. Some of the ants were completely paralyzed, while others moved their abdomens, legs, and mouth parts. All through the morning, the whole place was in a bustle, but when we came back, after eating our luncheon in a shady spot, quiet reigned; the colony seemed asleep, and although we waited for an hour not a wasp showed herself.

The ants that these wasps were bringing all had wings. The European genus Fertonius takes worker ants which can be picked up anywhere; but so far as we know, these queens leave the nest only at the time of their

nuptial flight, after which the wings are lost. How then are they captured? Can it be that the wasps, though not much larger than their prey, descend into the home of the ants, bearding the lions in their den, and carrying off their young queens by force of arms? This smacks of heroism.

Much interested in the matter, we carefully examined the ant-hills of the neighborhood. Those on top of the hill had openings too small to admit frigidus, supposing she had wanted to enter, but down on the roadside below we found some larger doorways and sat down beside them. We had scarcely arrived when a frigidus appeared on the scene, alighting six feet away. That she should have come hunting so soon seemed almost too good to be true, but she certainly was not doing anything else. She did not dig, nor feed on the clover, nor circle about as though looking for her nest, but began to clean and brush herself assiduously. Then she climbed a tall grass blade, and swinging at the top went through some curious gymnastic performances. Then she brushed herself again, drawing her third legs over the sides of her abdomen. This went on from moment to moment, until half an hour had passed, and more than once the painful suspicion crossed our minds that this was some trifling male putting in the hours between breakfast and

luncheon. One encouraging fact cheered us: aimless as the wasp appeared she was slowly drawing nearer and nearer to the nest; and at last, alighting on the top of a weed close by, she crouched there in a most peculiar attitude, and gazed intently at the opening. Absorbed and tense, she looked about to leap upon her prey; but after a time she relaxed and moved about a little. Presently she came close to the entrance and seemed on the point of going in; but the ants were swarming up and down, and we thought that perhaps that step required more courage than she possessed. At any rate, she did not enter, but hung about for some minutes and then flew away.

Was this a young wasp out on her first hunt? What strange antiphonal desires must have stirred at the sight of the nest, and how mysterious was the power that drew her to it! Was there in her brain any image of the queen she must seek and sting and carry away from among her guards and subjects? Or had she perhaps already achieved the adventure, and did the memory of the bitter nips that little ant jaws can give make it a harder task than it was the first time, when she risked the ills she knew not of? That she hesitated and carried on the work reluctantly seemed to show that her flesh was weak and needed the prick of conscience to drive it on.

Had we here then the small beginnings of moral sense and perception of duty? Can it be that of such humble origin is the power that "doth preserve the stars from wrong"?

We went on with these meditations for several days while lingering, with gradually diminishing hopefulness, over one ant-hill after another. The wasps were carrying in winged queens by the score, but they did not come our way to find them; and although we ranged about widely, we failed to see the capture. Occasionally we met a frigidus hunting, running about on the ground and poking her head, not only into ant holes, but into holes of all sorts, and as we sometimes saw young queens (wingless however) starting to dig their nests, we thought these might be the object of the search. The weather was cold and windy, most unpropitious for swarming, and yet frigidus was working as briskly as ever; so that we began to feel sure that she could not depend upon meeting the queens outside the nest, but must enter to get them. Just as this point we received a letter from Mr. William M. Wheeler, well known as an authority on ants, saying that he felt very sure that the wasp could not extract the queens from the nest, but must find them running on the ground, just after the nuptial flight, before they dug their holes and started their colonies.

Respecting this opinion, but still feeling unconvinced, we caught a wasp in a glass, and carrying it to an ant-hill, inverted it so that she was confined just over the entrance. After buzzing up and down for a moment, she alighted and walked calmly into the hole; but a fraction of a second later she came rushing madly out again, pursued by the most furious lot of ants that ever defended the home city against invasion. Down tumbled our air castles about courage and duty, for however frigidus gets her queens, it is not in that way. We have not yet seen the meeting and the capture, but hope that sometime we may be lucky enough to be on the right spot at the right time.

Chapter VIII

THE WOOD-BORERS

OUR two species of Trypoxylon are both slender-waisted black wasps, albopilosum having bunches of snowy white hairs on the first legs, and measuring three quarters of an inch in length, while rubrocinctum is a little smaller, and, as the name implies, wears a red girdle.

Although these wasps are called wood-borers, they will use convenient cavities in any material. When we went out to our summer cottage, in the last days of June, 1895, we found many little wasps of the species Trypoxylon rubrocinctum busily working about a brick smoke-house on the place. Closer examination showed that in the mortar between the bricks were many little openings leading back for a considerable distance, which were occupied by the wasps. It would seem that these holes were excavated by some other agency than the wasps themselves, as they were so much too deep for their purposes that before using them they built a mud partition

across the opening about an inch from the outside of the wall. Later we found nests of the same species in the posts which support an upper balcony of the cottage; and here, too, the wasps made use of holes which were already excavated.

In the following summer we found large numbers of these wasps at work in a straw-stack. The stack had been cut off perfectly smooth on one side, so that many thousands of the cut ends of the straws were exposed to view, and these proved very attractive to rubrocinctum. This species is very cosmopolitan in its tastes, for we found it utilizing the small holes in the sticks of a woodpile. The straws made the daintiest nesting-places, however, and were well adapted to our purposes, since they could be drawn out of the stack and split lengthwise so that the contents could be easily studied. The two halves could then be brought together again without injuring the inhabitants, and thus we often kept several sets under observation long enough to watch the changes from the egg to the pupa. We found Trypoxylon albopilosum nesting in holes made by beetles in posts and trees, but never in straws. A third species, bidentatum, was very common, nesting in the stems of plants. During the month of August we saw many individuals of this species hunting for spiders on the

blackberry bushes; but at this time we were so much absorbed in Crabro stirpicola that we never followed them to their homes.

Rubrocinctum was more conveniently studied, and through July and August we watched the comings and goings of these little wasps. They were very good-tempered, never resenting our close proximity nor our interference with their housekeeping. By working hard they could prepare a nest, store it with spiders, and seal it up all in the same day. This we have seen them do in several instances. In other cases the same operation takes three or four days. In the second summer that we worked with them we found one very energetic mother that stored four nests in one day. It had rained hard on the twenty-sixth of July, and no wasp works in such weather. On the afternoon of the twenty-seventh we took a straw just as the little mother was bringing in a spider. We opened it and found that the innermost cell contained eight Epeirids, with an egg on the abdomen of the last one taken in; the second cell was provisioned with ten spiders, with the egg on the seventh, so that three had been brought in after it was laid; the third cell had the egg on the last spider, as did also the fourth. All of these eggs hatched on the twenty-ninth, — the two outer ones, that were laid last, between eight and nine

o'clock in the morning, and the two that were laid earlier between two and three in the afternoon. This was the biggest day's hunting that we have ever recorded for any of our wasps.

With both species (T. rubrocinctum and T. albopilosum), when the preliminary work of clearing the nest and erecting the inner partition has been performed by the female, the male takes up his station inside the cell, facing outward, his little head just filling the opening. Here he stands on guard for the greater part of the time until the nest is provisioned and sealed up, occasionally varying the monotony of his task by a short flight. As a usual thing all the work is performed by the female, who applies herself to her duties with greater or with less industry according to her individual character; but the male doubtless discharges an important office in protecting the nest from parasites. We have frequently seen him drive away the brilliant green Chrysis fly, which is always waiting about for a chance to enter an unguarded nest. On these occasions the defense is carried on with great vigor, the fly being pursued for some distance into the air. There are usually two or three unmated males flying about in the neighborhood of the nests, poking their heads into unused holes, and occasionally trying to enter one that is occupied, but never,

so far as we have seen, with any success, the male in charge being always quite ready and able to take care of his rights. The males, however, made no objection when strange females entered the nest, as they sometimes did by mistake, nor did the females object to the entrance of a strange male when the one belonging to the nest happened to be away; but in such cases the rightful owner, on his return, quickly ejected the intruder. We often amused ourselves, while we were watching the nests, by approaching the little male, as he stood in his doorway, with a blade of grass. He always attacked it valiantly, and sometimes grasped it so tightly in his mandibles that he could be drawn out of the nest with it.

When the female returns to the nest with a spider the male flies out to make way for her, and then as she goes in he alights on her back and enters with her. When she comes out again she brings him with her, but he at once reënters, and then, after a moment, comes out and backs in, so that he faces outward as before.

In one instance, with rubrocinctum, where the work of storing the nest had been delayed by rainy weather, we saw the male assisting by taking the spiders from the female as she brought them and packing them into the nest, leaving her free to hunt for more. This was an especially attentive little fellow, as he guarded the nest

almost continuously for four days, the female sometimes being gone for hours at a time. On the last day he even revisited the nest three or four times after it had been sealed up.

It is upon the female that the heaviest part of the work devolves. As soon as she has put the nest in order she begins the arduous task of catching spiders wherewith to store it. It usually takes her from ten to twenty minutes to find a spider and bring it home, but she is sometimes absent for a much longer time. When the spider has been carried to the nest the process of packing it in begins. This occupies some time, and apparently a good deal of strength, — the female pushing it into place with her head, totally disregarding its comfort, all the spiders that are caught being pressed and jammed together into a compact mass. While she is busied in this way she makes a loud cheerful humming noise. The number of spiders brought seems to depend upon their size, in which quality they vary greatly, the largest ones being six or eight times as large as the smallest. Rubrocinctum fills her nest with from seven to fourteen, while the larger albopilosum brings as many as twenty-five or thirty. Those that we examined represented many different genera, and even different families, although they were usually orb-weavers.

In a number of cases, during the first summer, after several spiders had been stored, we gently drew them out with a bent wire. In one nest in which there were five spiders, we found, two hours after they had been stored, that three were alive and two were dead. In another, which the wasp had just begun to seal up, were ten spiders. Three of these were injured in being drawn out. Of the remainder four were alive and three dead. On the anterior part of the dorsum of one of the living spiders was the egg. It had probably been fertilized as the female carried the male into the nest on her back.

When we discovered rubrocinctum in the straw-stack, we made many observations as to the position of the egg and the number and condition of the spiders. We found that the egg was always placed either on the side or the back of the anterior part of the abdomen. The number of spiders stored was, as we have already stated, from seven to fourteen. A fact that interested us greatly was the remarkable accuracy shown by the wasp in never selecting too large a spider for the calibre of the straw. Oftentimes it was an extremely close fit, but it could always be squeezed down. When they nested in posts they used at times much larger prey. Unfortunately we never saw this species capture its prey, nor could we prevail upon it to sting in captivity, but the

number of spiders that we found in straws was so large as to afford abundant evidence concerning the degree of surgical skill possessed by the wasps. P. marginatus and P. scelestus, in overpowering their large fierce Lycosids, must sting when and where they can, but most of the spiders taken by rubrocinctum are inoffensive creatures, and there is so little need to be careful

TRYPOXYLON RUBROCINCTUM

or adroit in dealing with them that she has time and opportunity to sting the exact spot that will give the best results.

The concentration of the nervous system in the Arachnida would seem to conduce very strongly to uniform results from the stinging of the wasps. Unlike the larva

used by Ammophila, with its chain of ganglia, in the Araneidæ the whole central nervous system, including the brain and the ventral cord, forms a single mass, pierced by the œsophagus. The greater part of this mass, which lies behind the œsophagus, represents the fused ventral cord from which the nerves radiate. It is evident that a thrust given in almost any part of the ventral face of the cephalothorax, or even on either side of the anterior half of its edges, would reach the nervous centre. With these facts before us let us turn to the notes made upon the condition of the spiders that had been stung and stored up in the nests of the straw-stack. By the "first cell" we mean the last one stored, which was naturally the first one opened.

July 11. Opened a nest of *rubrocinctum*. The first cell contained fourteen live spiders with a newly laid egg. Some of the spiders were very lively, moving spontaneously. Second cell, ten spiders, one dead, others alive, and an egg. Third cell, eight spiders, three dead and five alive, and the egg.

July 12. In each of the first and second cells one spider has died since yesterday, while in the third there is no change in their condition. The egg in the third cell hatched at nine in the morning, and the one in the second cell at three in the afternoon.

July 13. In the first cell all the spiders are dead but one,

and in the second, all but four, while in the third none are alive.

July 15. All the spiders in the second cell are dead.

July 16. The one spider in the first cell has outlived all the others, but that, too, died to-day.

The record of another set of nests is as follows: On July eighth we took a straw with a wasp as she went in with her spider. The cell was not sealed up. It contained fourteen specimens of three species of orb-weavers, and the egg was apparently just laid. The spiders were pushed in very tightly, and the legs and abdomens were, in many cases, bent to one side. All were limp, but alive. By July tenth, four were dead; on July eleventh the egg hatched. By July thirteenth all of the spiders were dead.

It is unnecessary to give the history of other nests in detail, since these facts make it clear that there is a great variation in the degree of severity with which the spiders are stung, so that while with some the paralysis is complete, with others it is only partial. Some were killed outright, others lived two or three days, while still others survived for two weeks. Compared with the work of the Pelopæi it would seem that a smaller number of the spiders are killed at once, while a larger number die after the lapse of a few days. None of the victims of

Trypoxylon live so long as the most perfectly paralyzed spiders of the mud-daubers. Two of them lived ten and fifteen days respectively, while with Pelopæus one survived until the thirty-eighth and one until the fortieth day.

The egg requires from forty to sixty hours for its development, and the larva feeds for seven or eight days before spinning its cocoon. Those that we watched usually disposed first of the abdomen and then of the cephalothorax; sometimes they would consume several abdomens before attacking the other parts. After the body was devoured the legs were picked up and eaten. When the supply of food was generous, portions of the spiders were sometimes left untouched. The cocoons resembled in general appearance and structure those of Pelopæus.

When a female returns with her load she usually hunts about for a few moments before finding her nest, sometimes entering, first, two or three that are empty or are occupied by other wasps; but we do not wish to cast any reflection upon the sense of locality of a creature that is able to find one particular straw out of the many thousands in an expanse of stack twenty feet high by twelve wide. We ourselves can testify, from experience, to the extreme difficulty of the task.

After the storing process is completed the female seals up the nest with mud. In the case of one rubrocinctum that we were watching, she began to close the opening at four in the afternoon and finished her work just thirty minutes later. In this time she made ten journeys for mud, bringing it in pellets in her mandibles. In another case, also a rubrocinctum, the female, after bringing so many spiders that the cell was full up to the very door (which we saw in no other case), went away without closing it, and never returned. The male seemed uneasy at her conduct, and several times flew away, staying an hour or two and then returning; but after a time he too deserted the nest. Whether some evil fate overtook the female or whether there was some failure of instinct on her part, can only be conjectured; but the latter hypothesis is not untenable, since out of seventy-six nests that we had under observation seven were cleaned out and prepared and were then sealed up empty. We have often found similar cases among the nests of the blue mud-dauber wasps, where it is not a very uncommon thing for the absent-minded females to build their pretty little cylindrical nests with infinite care and patience, and then to seal them up without putting anything inside.

Cocoons of rubrocinctum that were gathered in the

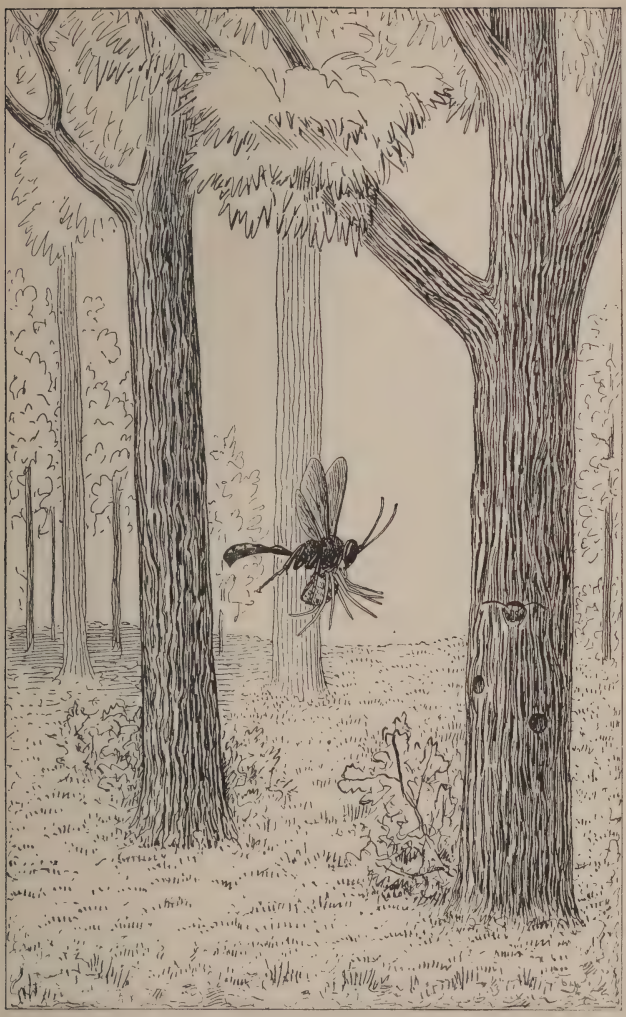
month of August remained over the winter and hatched in May and June.

Almost as interesting as rubrocinctum is the slightly larger species, T. albopilosum. This wasp has a great liking for the posts that support the balcony of our cottage, a preference that is very convenient for us, as it enables us to sit in the shade and watch their doings at our ease.

One afternoon as we sat, literally, at our posts, a female of albopilosum came humming along, looking very important and energetic, as though she had planned beforehand exactly what to do. She entered an empty hole, head first, and at once began to gnaw at the wood, kicking it out backwards with considerable violence. After a few minutes she changed her method of work, and began to carry out loads of wood dust in her mandibles, dropping it in little showers just outside the nest, and then hastening back. In forty minutes she carried out, in this way, upwards of fifty loads. She then flew away, but returned in ten minutes with a male. She alighted, he took his place on her back, and they went in together.

After a time they came out and both flew away, but the next morning they came back and the nest was stored.

In this species the male does not always come out of



MALE TRYPOXYLON AWAITING THE FEMALE

the nest when the female brings a spider, the nest being enough larger than in rubrocinctum to accommodate them both comfortably. As a usual thing, however, he enters on the back of the female. The spiders brought by albopilosum are larger than those used by rubrocinctum. They sometimes bring such heavy specimens of Epeira insularis that they are carried with difficulty, the wasp alighting and dragging the spider into the hole instead of flying directly in as usual.

We watched a number of albopilosum nests during the second summer, finding them in several instances through the loud humming of the female while she was pushing the spiders into her hole. From our not very extensive study of the spiders taken by this species we are of the opinion that some are killed at the moment of capture, while others that are only paralyzed die in the nest from day to day.

Mr. W. H. Ashmead has noted that albopilosum stores its nest with aphides, but in the cases that we observed they used only spiders. There can be no mistake on this point, as we more than once took the spider from the wasp as she was entering the nest. In a recent letter Mr. Ashmead says that his notes were made in the field, and that he probably mistook some closely allied species for this one.

We are not as familiar with the habits of T. bidentatum as with those of the other two, but we have a few notes relating to the female. This little worker is the smallest of the three, and like her sisters is a confirmed spider-hunter. Once, when out among the raspberry bushes, we had the good fortune to witness a capture. The wasp seized the spider, as it rested on a leaf, by the top of the cephalothorax, and, holding it firmly, curved her abdomen under and stabbed the ventral face of the cephalothorax. All her motions were deliberate, and after the operation she delayed a moment before picking it up by a leg and flying off. We often found raspberry stems which had been filled with spiders by this wasp, but we do not know the length of time required for the development of the egg, nor how long the larva eats before pupation. The cocoon is very different in appearance from those of rubrocinctum and albopilosum, being exceedingly long, slender, and almost white, instead of short, wide, and brown. The perfect insects come out in September, and the last cocoon formed is the first one to hatch. This was also true of the cocoons of rubrocinctum formed in straws.

Years ago, when we found that many of the orb-weavers laid enormous numbers of eggs (A. cophinaria from 500 to 2000), we wondered what became of the

thousands of spiderlings. An acquaintance with Trypoxylon has shown us their fate, and has given us an illustration of how closely the two groups are related. To make a very modest estimate there must have been twenty wasps at work in our straw-stack. During the six weeks which make the busiest part of their working season each of these must have stored, at the very least, thirty cells, putting an average of ten spiders into a cell. It may then be considered certain that the straw-stack, with its working surface of twelve by twenty feet, was the mausoleum of six thousand spiders, and it is very probable that twice as many were interred within its depths. It must be remembered, too, that before the spiders have grown large enough to be interesting to rubrocinctum, bidentatum has had her turn at them, and that those that are allowed to grow too large for rubrocinctum are preyed upon grade after grade, first by albopilosum and finally by Pelopæus, Pompilus, and other genera.

The wasps of this genus lose their interest in family affairs about the second week in August, though after this time they may still be seen taking their well-earned holiday on the blossoms of the aster and the golden-rod.

Chapter IX

THE SPIDER-HUNTERS

WHILE Ammophila provides caterpillars for her larva, and Bembex, after the manner of the social wasps, feeds her young from day to day on dead flies, the Pompilidæ, so far as their habits are known, all prey upon spiders. The family is a large one in the United States, one hundred and twenty-seven species having been described. The members of the group differ in size, color, and habits, and the individuals of the same species show the very considerable amount of variation which seems common to all those groups of animals which have been carefully studied. Happily the old notion that habits and instincts, unlike structural peculiarities, are always uniform, is no longer insisted upon, and there is ample evidence for the opinion that functional variations are as common as morphological. We have studied five species of this family, and have found their respective rôles of great interest.

According to Fabre, the French members of this

genus, although they do not make their own nests, still exercise some foresight in the matter by selecting a suitable crevice before catching their prey. Among the species that we have studied, quinquenotatus, biguttatus,

TORNADO WASP (POMPILUS QUINQUENOTATUS) DIGGING NEST

fuscipennis, marginatus, and interruptus first catch the spider and then make the nest; while calipterus and scelestus prepare the nest before capturing their prey.

Quinquenotatus is usually rather less than half an inch in length and is black, the abdomen having a variable number of white bands and a white tip.

It was on the last day of July that, as we were walking through the bean field, we saw a cloud of fine dust which came spurting up out of the ground like water in a fountain. By watching intently we saw that the cause of the commotion was the rapid action of the legs of some little creature that was almost hidden in the earth, and this proved to be our first example of P. quinquenotatus.

She was working away as furiously as though she had studied the poets and knew her *carpe diem* by heart. Faster and faster went the slender little legs; higher and higher rose the jet of dust above her. Then suddenly there was a pause. The burrower had met with some obstacle. A moment more and she came backing out of the hole, her feet slipping on its crumbling edges. In her mandibles she carried a pebble, which was taken to a distance of four or five inches. Then, moving quickly, she swept away the dust that had accumulated near the mouth of the nest, reëntered the hole, and resumed the labor of excavation.

We thought that the rate at which she worked was too violent to be kept up very long; and sure enough, before ten minutes had passed the nest was deep enough for her purposes, and we afterward learned, to our chagrin, that it was too deep for ours. The wasp came out,

circled round the spot three or four times, and then flew off like a hurricane. Never have we seen a creature so fiery, tempestuous, cyclonic. Before we knew her proper title we took to calling her the tornado wasp, and by that name we shall always think of her.

POMPILUS QUINQUENOTATUS

Her flight was too rapid to follow, but in a minute we saw her returning. She was carrying a spider, a good-sized specimen of Epeira strix, which she had evidently deposited somewhere in the neighborhood before beginning to dig. Alighting near by, she left the spider lying on the ground, while she ran to her nest and kicked out a little more earth. Then seizing it by one leg, she dragged it, going backward herself, into the nest. She remained hidden for about two minutes, then reappeared, and, seeming to be in as great a hurry as ever, filled the hole with dirt. To disguise the spot and render it indistinguishable from the rest of the field was her next care. Hither and thither she rushed, now bringing little pellets of earth and placing them above the nest, now sweeping away the loose dust

which might suggest the presence of the *cache*, and now tugging frantically at a stone which she wanted to place over the hidden treasure, but which was too deeply embedded in the earth to yield to her efforts. She did her work faithfully, although with such eager haste that all was completed at the end of twenty minutes from the time we saw her first. So well was the place hidden that it was only by careful orientation that we could be certain of its exact locality.

Her task accomplished, away flew our little tornado as though she were pursued by the avenging spirits of all the spiders that she had murdered, although more probably she was off in quest of another of those meek and helpless victims.

"Now," we said, "we will trace out the nest and make a drawing of it. We will take the spider home and note its condition from day to day, watching at the same time the development of the larva."

Enjoying this little air-castle, we began to excavate. Having had experience with the nests of Ammophila and Diodontus, and knowing that the task might not be so easy as it looked, we went to work with all possible care. It seemed, however, that some magician's trick — some deception of the senses — had been played upon us. We saw the spider interred; we at once dug

up the place and found nothing. Slowly and carefully we enlarged our circle. We went down deeper until the opening was large enough to hold a thousand spiders, — still nothing. Then we tried another plan. Gathering all the earth that we had taken out, we sifted it through our hands — in vain. At last we acknowledged ourselves beaten, and trudged home empty-handed.

Our pride was destined to be still further humbled. Three times within that same week we saw the tornado wasp bury her spider, and three times we failed, just as incredibly, to find it. On the last of these occasions we did not let her fill the nest, attempting to follow the tunnel and get out the spider as soon as the egg was laid, but the loose, unstable character of the soil defeated us.

Our fifth example, however, dug her nest, not among the beans but lower down in the potato field, where the ground was firmer; and here we made our first successful excavation, — successful only up to a certain point, since in getting out the spider we dislodged the egg, and although it was at once replaced it never developed. The spider was placed three inches below the surface, but we could not trace the tunnel. At our next opportunity, wishing to make good this failure, we placed a blade of grass in the opening just after the wasp began

to fill it. On being disturbed she assumed the most comically threatening aspect, whirling around, lifting her wings, and then circling about us. As soon as we moved back she dashed at the grass-blade and pulled it out with great energy. A few minutes later we made a similar attempt, and again she frustrated our plan; but when we inserted the grass-blade for the third time, the nest being now half filled, she let it remain. Some hours later, with this to guide us, we succeeded in tracing the nest, but much to our disappointment found it transformed into a banqueting hall. Scores of tiny red ants had discovered this rich store of food. They had eaten the egg and were rapidly finishing the spider.

Twice afterward, in opening these nests, we found the same ants in possession before us. It is probable that they are a formidable enemy to this and other species of Pompilus; but they seem to find the spider by burrowing beneath the surface, so that the elaborate hiding of the nest from above cannot be meant as a protection from them.

Pompilus quinquenotatus has a decided preference as to the spider that she takes. While Pelopæus and Trypoxylon are entirely indifferent both as to size and species, and the more nearly related Pompilus marginatus takes Thomisus, Drassus, Attus, Agalena or

Lycosa, this more fastidious wasp will not be tempted from the spider of her choice. In more than fifty examples the victim in the play was invariably Epeira strix. If she must confine herself to one species she has made a fortunate selection, since there is no other spider so common in our neighborhood, not only in the woods,

EXAMPLE OF EPEIRA STRIX THAT HAS BEEN PARALYZED AND HUNG UP ON BEAN PLANT BY POMPILUS QUINQUENOTATUS, THAT IT MAY BE OUT OF THE WAY OF ANTS WHILE SHE DIGS HER NEST

but around the barns and outbuildings. Most frequently it was the female that was taken, but this does not imply a preference for that sex, since the females are more

abundant than the males. We have never seen the spider captured and do not know where the sting is given, but certainly this wasp wounds her prey very severely. The spiders that we took from her were either dead, or so completely paralyzed that it required great care and the use of a magnifying glass to determine that they were alive.

The next stage of her proceedings we are familiar with, as we have frequently seen the wasp carry the spider. Unlike her sister, marginatus, she usually flies with it, and seems not at all encumbered by its weight. In many cases, however, she drags it, holding it by one leg and running rapidly backward.

A suitable place for the nest being found, the spider is very prettily taken care of while the work is in progress. A plant, usually a bean or a sorrel, is chosen, and the strix is hung in the crotch of a branching stem, where it will be safe from the depredations of ants. This precaution is not always taken. We have many times seen the spider left on the ground, although there were plenty of plants at hand.

The next point is to decide upon the precise spot for the nest, and here our wasp shows herself very uncertain and hard to please. Never have we seen one settle down and complete her work in the spot first

chosen. She dashes at a place and scratches and digs away with furious energy for a few minutes, and then, starting up, she darts wildly hither and thither until a new place, near by, is fixed upon and another beginning made. In one instance eight nests were started and some of them nearly finished, the little worker seeming to be beside herself with excitement. After the decision is finally made the tunneling is a rapid process. In one case it took the wasp a whole hour to complete the work, but out of the thirty nests that we saw made, nineteen were finished in from twenty to twenty-five minutes. Like Fabre's Sphex the wasp interrupts herself three or four times to visit her spider and make sure that it is safe. When all is done she brings the strix to within a foot or two of the opening, runs to the nest to take a final look, and then, going backward herself, pulls it inside.

In two instances we saw the fidgety little creature go through a most comical performance, which again recalls the Sphex of Fabre. Leaving her treasure on the ground, she ran to the nest and kicked out a little more earth; hastening back she dragged it an inch nearer; then away she went to the nest again for more digging, and so on, dropping her spider half a dozen times before she at last brought it home. In two other

cases in which there was no such anxiety about the size of the nest, there was, in reality, more reason for it. Indeed, in one instance the opening had to be enlarged before the spider could be taken in. There is a wide-winged parasitic fly that, having nothing else to do, lays prodigious numbers of eggs, not in any particular nest, but at the edge of holes wherever it may chance to see them. It hovers about over the ground until it comes to an opening, dips down twice or thrice, ovipositing each time, and then passes along. The habit of scratching out a little dirt at the threshold, just before the prey is brought in, seemingly from a desire to enlarge the nest, or in other cases from mere nervousness, is perhaps of use in destroying these eggs, which might otherwise adhere to the spider or caterpillar as it is dragged over them.

The laying of the egg takes only two or three minutes, and then the hole is filled up. In this part of her work quinquenotatus shows a great deal of variation, sometimes coming out of the hole and sweeping in the dirt with her first legs and sometimes standing in the tunnel while she draws the earth in with her mandibles and then jams it down with the end of her abdomen. The former plan was in vogue in the garden, while the latter was more common with the wasps on the island. After

the hole is filled the spot is covered with pellets of earth and pebbles brought from a little distance, very much as is done by Ammophila.

When we found that quinquenotatus was a very common species, and that nearly every day brought us a fresh example, we thought that we had the question of its stinging habits in our own hands. What could be easier than to carry a strix about with us and to exchange it, when opportunity offered, for the paralyzed spider of the wasp? The good results obtained by Fabre and Marchal from this manœuvre made us confident of success. We did not doubt that when the wasp came for her spider and found it livelier than it ought to be, she would repeat the stinging operation before our eyes.

Accordingly, the next time that we saw quinquenotatus digging we made a diligent search for her spider, and soon found it on a bean plant five feet away. Just as we discovered it, however, the wasp swooped down and carried it to some purslain, close to the hole, where she hung it up again, while she went to make her final preparations at the nest. We seized our chance, and quickly substituted a fresh strix for the one that had been paralyzed. According to the habit of its species when danger threatens, it kept perfectly quiet, and when

the wasp returned it was hanging there as motionless as a piece of dead matter. How she knew the difference was a mystery, but she would not touch it. She seemed to think that she had made a mistake in the locality and that her own spider must be hanging somewhere close by, for she hunted all over that plant and then over several others near to it, returning continually to look again in the right spot. After five minutes she gave it up, circled about three or four times, and flew off in the direction of the woods to catch another spider.

Why did she go to the woods? When she realized that the strix she had stung was gone and that she must have another, why did she not take the one that hung there in plain view? Our failure could not have been due to the fact that we had handled the spider, since, when on other occasions we took one that had been paralyzed, examined it and then returned it to the wasp, she accepted it without hesitation.

Disappointed though we were at the irrational conduct of our wasp, we resolved to await her return and to try again. In forty minutes she came back with another spider, but instead of taking it into the nest she hung it upon a bean plant near by and then proceeded to dig a new hole a few inches distant from the first. Foolish little wasp, what a waste of labor! Truly, if

you are endowed with energy beyond your fellows you are but meagrely furnished with reason.

Again we availed ourselves of our opportunity, and substituted our spider for hers. This time it had grown weary of playing its motionless rôle, and frequent readjustments were necessary in order to keep it in position. At the moment that the wasp came back to take it, the spider scrambled from its place and began to make its way along the stem. The wasp evidently saw it, for she hovered over it a moment. She then flew to the next plant, where she hunted about over the leaves and branches in search of her lost treasure. After a time she returned. The spider had now come to a standstill, and the wasp examined it attentively, although without touching it. She then flew away without circling at all, which might, perhaps, be taken as an indication that she had no intention of returning to a place where she had fared so badly.

Just at this moment we chanced to see another paralyzed strix hanging near by. Again the exchange of our specimen was accomplished; but when the second wasp came to find her spider she gave us no more satisfaction than the first. The substitute hung there quietly enough. We ourselves could not have distinguished it from the original, but quinquenotatus took a good look

at it, decided that something was wrong, hunted about a little for her own spider, and then flew away.

We had then, as the fruit of our morning's work, gained nothing in regard to a knowledge of the stinging habits of our wasp, but at least we had secured three freshly paralyzed spiders to add to our laboratory collection. As to the strix that had so kindly assisted us in our experiments, we placed it on a bush in the pleasantest and most secluded corner of the garden and left it there, wishing it a long and happy life.

Later on in the season we tried the same experiment. Taking her spider from quinquenotatus as she was dragging it to her nest, we offered her a very lively strix in its place. She would not notice it at all, and soon flew away. Half an hour later she reappeared, and seemed to be looking for a place to dig. As she ran about on the ground we offered her another spider, dropping it on the ground in front of her. This one behaved admirably, drawing up its legs and keeping perfectly still, not moving even when she felt of it and turned it over, but it was left without any display of interest or emotion.

One day we saw a quinquenotatus finish her nest and go after her spider. She was absent for some time, and when an ant passed by, dragging a paralyzed strix that had evidently been stolen from some wasp, we thought

that the one we were watching had been robbed, and rescuing the spider, placed it in the doorway of the nest. We had judged wrongly, for a moment later our wasp came back bringing her own spider, and dropping it near by, ran to look at her nest. She was disturbed at finding the way blocked, and dug out a little earth to one side of the strix. Then she flew to some holes in the ground not far away and dug a little, first in one and then in the other. After this she took a look at her spider, and then went back and dug a little more at her own nest. Finally she seized the impeding strix by a leg, dragged it out of the way and paid no further attention to it, storing her own spider and departing, although the one she had rejected might have saved a hunting expedition.

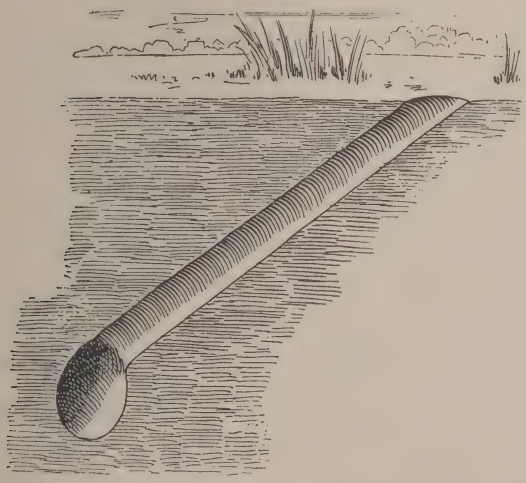
At another time we saw two wasps digging their nests two or three feet apart. One of them finished before the other, and being unable to find her own spider (probably it had been carried away by the ants), she seized that of her neighbor and bore it away. The rightful owner saw from a distance what was happening, and ran to the rescue. A violent scrimmage ensued, the two wasps clinching and rolling over and over together. The robber escaped and made off, but was followed and caught again. She fought so well for her ill-gotten treasure,

however, that she finally conquered the other and hurried off with her prize. She showed by her manner that she felt the need of haste, for instead of laying the spider down and looking at the nest, she dragged it directly in, as though she feared another attack. This was the first time that we had ever seen these wasps fighting over their prey, and we were surprised to find that they would take spiders which they had not captured themselves, since when we had tried to exchange with them they had refused to carry out our scheme. This was clearly an intelligent act, and could not be an affair of instinct.

Once again we witnessed a similar struggle. One of these wasps was laboriously dragging her strix up a steep hillside, when a much bigger one of the same species descended upon her and seized the spider. She was loath to give it up, and they both pulled until it seemed as though the poor creature would be dismembered. The highway robber came off victorious, and after flying to a distance hung the spider up while she finished a partly made nest, and then stored it away. It may be said in extenuation of her conduct that since she had a nest started she had probably been robbed herself, and therefore felt that she was entitled to a spider.

The nests of quinquenotatus vary considerably according to the kind of soil in which they are made, the

firm clay of the garden giving a result quite different from the fine dry earth of the island, in which they are usually much larger, and scarcely to be distinguished from the holes of Bembex spinolæ. In both localities,



NEST OF P. QUINQUENOTATUS

however, the nest consisted of a short tunnel, running obliquely downward, with a slight enlargement at the end, but with no change in the direction of the gallery.

In the loose sand of a steep hillside we found that the wasps had a different method. Their tunnels in this place filled up nearly as fast as they could dig them, and when they had reached a depth of half an inch they

turned off at a right angle, and excavated in an entirely new direction. They probably derived some advantage from this variation, for we saw four in succession follow the same plan, which certainly appeared to be an intelligent adaptation of means to ends.

We once saw a wasp of this species digging her nest on the Bembex field. When finished it was a large hole which could not have been distinguished from those of spinolæ, which were open all about, the weather being bright and sunny. She flew off, and soon reappeared with her spider, which was dropped three feet away while she ran to make sure that all was right; and now followed something that we had never seen before — she could not find her nest. She flew, she ran, she scurried here and there, but she had utterly lost track of it. She approached it several times, but there are no landmarks on the Bembex field. We have often wondered how they find their own places. After five minutes our wasp flew back to look at her spider, and then returned to her search. She now began to run into the Bembex holes, but soon came out again, even when not chased out by the proprietor. Suddenly it seemed to strike her that this was going to be a prolonged affair, and that her treasure was exposed to danger; and hurrying back she dragged it into the grass at the edge of the

field, where it was hidden. Again she resumed the hunt, flying wildly now all over the field, running into wrong holes and even kicking out earth as though she thought of appropriating them, but soon passing on. Once more she became anxious about the spider, and carrying it up on to a plant suspended it there. Now she seemed determined to take possession of every hole that she went into, digging quite persistently in each, but then giving it up. On one that seemed to be unoccupied she labored at enlarging the entrance, until we thought that she had mistaken it for her own, or at least had determined to use it. At last, however, she made up her mind that all further search was hopeless and that she must start afresh; and forty minutes from the time that we saw her first she began a new nest close to the spider, as though she would run no more risks. This nest was successfully completed, and the spider was stored away without further misadventure.

The egg of quinquenotatus can be but lightly attached to the spider, for only once, out of many attempts, did we succeed in getting it out without displacing it. In this case three days elapsed before it hatched. The larva ate for a day or two, but then pined away and died. Another nest was opened on the tenth day after the egg was laid, and in this the spider had been entirely eaten

and the larva was just spinning its cocoon; so that the larval stage probably occupies about a week.

A summary of our notes shows a very wide variation in the condition of the spiders stored by this wasp. Out of eleven that were stung three were killed at once, two lived four days, one five, one eleven, one twenty-three, one twenty-five, one thirty-one, and one at least forty days and probably longer.

We look back with much pleasure upon our acquaintance with this gay, excitable little wasp. She was so full of breezy energy that it was always delightful to meet her, and she showed so wide a variation in individual character that we seldom watched her without learning something new.

Pompilus fuscipennis, a little smaller than P. quinquenotatus, is black, with the red girdle that appears so frequently among the solitary wasps. The first time that we ever saw this wasp she was running rapidly backward over the bare ground, the brilliant red of her body flashing in the sunlight as she dragged along a little spider of the genus Thomisus. Presently she carried it up on to a leaf and began to bite at it, but being disturbed by an ant, hurried on with a much agitated manner. Soon she stopped again and resumed her attack, biting savagely at the legs near their junction with the

body, and now, looking closely, we saw that two of them had been completely cut off. While occupied in this way the wasp was evidently intensely excited. She lay on one side with the abdomen bent under, turning the spider over and over as she worked. After a time she carried it onward to the potato-field, where the plants afforded some shelter, and placing it upon a leaf, well above the ground, began to dig near by. She worked almost entirely with her mandibles, lying sometimes on her side and sometimes on her back as she cut away the earth, which was pushed out with the end of her abdomen. When she had worked for ten minutes and had gone in the length of her body, she picked up the spider and rapidly made off with it, several times rising on her wings and flying backward for a few inches. A little further along she again deposited it on a leaf and began to dig in a fresh place. At the end of twenty minutes the nest was ready, but in bringing the spider she missed her direction and carried it to one side. Dropping it on the ground, she began to hunt about for her hole, but was distracted with excitement and ran so far afield that we feared she would never find it. At last, however, she came to the place, ran in for a moment, brought the spider nearer, dropped it and ran to the nest once more, caught it up again, and tried to

back in with it. She was holding it by the under side of the body, the venter being toward the hole, and the legs spread out and stopped its entrance. A moment's tugging convinced her that this would not do, and she then turned the spider over, holding it by the back, whereupon the legs at once folded themselves across the underside of the thorax, and it was drawn out of sight.

After the egg was laid the wasp came up to the edge of the hole, and drawing in some earth with her mandibles began to dance up and down upon it, jamming it into place with her abdomen. Afterwards she came up higher and drew the dirt in with her first legs, not getting out of the hole until it was entirely filled up. Then began a remarkable performance. Bracing herself firmly on her legs she used the end of her abdomen as an instrument, and with it she now pounded the earth, now *rubbed* it, like a pestle in a mortar, and now used it as a brush to sweep away loose dust. Sometimes she would throw a little earth back under her body with her mandibles and rub it down with her abdomen. This part of the work being finished, she spent a few minutes in sweeping the ground with her first legs, and then brought a quantity of small objects and placed them over the nest, — a little stick, the petal of a faded flower,

a scrap of dead leaf, and so on, until ten or twelve things had been collected. This artistic finishing up of her duties recalled Ammophila; but among our subsequent examples of fuscipennis we never saw one do her work with such nicety. They were usually contented to fill in the nest more or less compactly, sometimes doing much of the work from the outside, to brush off the surface without any rubbing or pounding, and then to bring two or three little pebbles or lumps of earth to place over the spot.

So far as we were concerned this was one of the most fearless of the wasps, not even interrupting her work when we once placed a glass over her as she was filling her nest; but the approach of an ant would throw her into a perfect panic, and seizing her spider she would make off with every sign of terror. It is difficult to understand why wasps of this species, as well as of biguttatus, never offer combat to the ants that rob them right and left, but invariably seek safety in retreat. Their attitude toward other robbers is quite different. We once saw a fuscipennis that was dragging a Lycosid attacked by a bigger wasp of the same species. Number One left her spider on the ground and chased Number Two to a distance; but no sooner had she returned and taken it up than Number Two, bold and unashamed, was at her

heels again, and the scene was repeated. The object of the robber was to seize a leg of the spider, and whenever she succeeded in doing this she jerked it free, and made off with it very rapidly; but when the owner pursued and caught up with her she relinquished the prize without a struggle. Why did she? She was the bigger and the stronger, and possession is nine points of the law in Waspland as elsewhere; but conscience made a coward of her, while the other was strong in her righteous cause. After a time we captured the little pirate; but now the nerves of the rightful owner were completely upset, and she flew away, deserting the spider for which she had battled so bravely.

The most interesting thing about fuscipennis is her habit of biting the legs of her victims. The instinct is very irregularly developed, since four out of ten spiders had not lost any legs, while the others had been deprived of one or two. No one who has watched the wasp can doubt that the habit is related to the fact that she makes a very small nest in comparison to the size of her prey. The spider never went in easily, always requiring to be shifted and turned and tugged at. There was an especial tendency to bite at the legs at this point of time, when the wasp, standing within the tunnel, was trying to drag the spider down. In one instance she managed to get

it past the entrance, but it stuck in the gallery; and after working at it in that position for a time she brought it out, subjected the legs to a severe squeezing, and then tried again. It was still a very bad fit, but by turning it about and pulling at it she succeeded in getting it in. It may be that the object of biting the legs is not to remove them, but to render them limber so that they will bend easily. Whatever the process may be, it is repeated at intervals from the time the spider is captured. As she carries it, the wasp pauses again and again, now on bare ground and now in a sheltered place or on some plant, to renew her efforts at getting the legs into a satisfactory state.

P. fuscipennis rarely circles about when leaving a place; this is unfortunate, since her sense of locality seems to be particularly weak. She nearly always has to hunt for the plant upon which she has placed her spider, and always loses track of her nest when she tries to bring the spider to it. We once caught her as she was carrying her spider, and then released her on the same spot; but she became so much confused that without our assistance she would never have found it again.

Our acquaintance with Pompilus marginatus began in the middle of July. She is a small creature, only half an inch long, and is dressed in black, with a bright

orange spot on each side of the anterior part of the abdomen. We were watching the pretty little Diodonti, as they filled their holes with aphides, when we saw her going backward, dragging along a medium-sized spider. Soon she came to an onion flower that was lying on the ground. Here she stopped and, after a moment's hesitation, drew her prey in among the blossoms of the cluster so that it was hidden from view. It was not long before she came out and began to fly about near the ground, frequently alighting to poke her head into cracks and to run again and again into little chance holes. Never did an insect behave in a more demented manner, and although there may have been a method in her madness it was difficult to discover it. No hole nor cranny pleased her, and back she flew to the onion to see whether her booty were safe. For fifteen minutes she ran and flew now here, now there, hurry and anxiety in every movement, returning frequently to reassure herself about the spider. Several times she entered a hole at the base of a weed, not a made nest, but an accidental crevice; and this spot was at length chosen either as a temporary or a final resting place for her spider, since she dragged it from the onion and deposited it here. We tried to capture the wasp; but having failed in this, we dug out the spider. It was three inches

down, the hole being deeper than it looked from the outside. There was no egg upon it. Evidently the work had not been finished, for the restless creature returned fifteen times within an hour to the broken nest, either for the purpose of laying her egg or to remove the spider to another resting-place on her homeward way.

POMPILUS MARGINATUS

This was our first specimen of marginatus, and a month passed before we met another. It was while watching some Bembecidæ that we saw the pretty little orange-spotted worker dragging a small Thomisid across their nesting-ground. The spider was so small that she held it in her mandibles well above the ground, and we speak of her as dragging it only because she walked backward and acted as though she were obliged to exert herself. Quite often the spiders taken by this species are too large to be carried, and then it is necessary to drag them; this habit is so ingrained that when it would be much more convenient to go straight ahead they stick to the ancient custom, and seem unable to move in any other way. This little wasp was in a frantic hurry, running backward into the

Bembex holes and then scrambling out again, until she had crossed the field and had turned to one side, having gone, since we first saw her, about fifteen feet. Here she dropped the spider and began to skim over the ground — it could not be called running and yet it was not flying — until she found a circular hole in the black earth, which looked as if it ran vertically downward. At the time we thought that this was a nest that she had made for herself, but we afterward concluded that it had been excavated by some other creature, that she had found it and determined to make use of it, and that she was bringing her prey to the spot with that end in view. Without entering she rushed back to the spider, but after carrying it a few inches, dropped it and ran to take another look at the nest. By this time, however, she was too much excited to know what she was about, and for five minutes she scurried over the ground without finding it. During this time she picked up the spider four times, carried it a little way, and then dropped it. The last time she carried it to the edge of the grass and stowed it there, this being her first attempt at concealment. She now found the hole again and brought the spider nearly to it, but by this time she was perfectly beside herself. The spider was seized again and again, only to be dropped the next second,

while the wasp rushed back and forth between it and the hole. In time this method of procedure brought it close to the nest, but it was carried around the edge once or twice even then. At last, accidentally as it seemed, it fell in, when the wasp quickly ran in also and pulled it down. For half an hour she remained inside, and when she came out we caught her to make sure of her identity. As we set her free immediately we expected her to go to work at covering her nest, but in this we were disappointed, for she did not return. We left the place undisturbed from the thirteenth to the fifteenth of August, when we dug up the nest. The Thomisid was there, but we could find neither egg nor larva. The spider was alive, as was shown by a quivering of the legs. This quivering grew fainter and fainter, until upon the nineteenth it was scarcely perceptible, and on the twenty-first the spider was dead. Our first spider had been stung to death at once, while this one lived seven days and a half after being stored.

On September first, while out in the bean patch, we saw a large Lycosid running madly, first in one direction and then in another. Hovering eagerly and excitedly just above was our marginatus, dashing down at the spider again and again as it came into view for an instant, and then circling wildly around until it

appeared once more. Now she pounced upon the frightened spider but missed her aim, now she really grasped it but was shaken off. At last the end came. The wasp descended upon the doomed spider, and there was a violent struggle, both the combatants rolling over and over upon the ground, while all that we could distinguish was the flashing of the red upon the body of the wasp. In an instant it was over, and the wasp rose, leaving the spider limp and motionless upon its back. In our other examples of marginatus the spider taken had been so small that the wasp might easily have held it and thrust her sting into any spot that she pleased, but this Lycosid was a different antagonist. Where the two were so nearly matched, there could have been but slight opportunity for skillful surgery. In point of strength the wasp was at a disadvantage, and she must have come off victor by the quick use of her sting. Under these circumstances she must have struck when and where she could, without selecting any particular spot. That she quite realized the power of her foe was shown by her next action. With the utmost circumspection she settled down upon the spider and made a prolonged and careful examination of the mouth parts. The investigation was satisfactory, and without any further stinging she seized the spider by

one leg, and this time really dragged it off. It was a good load for her, and it evidently required all of her strength to pull it along. Not far away was a lump of earth, under which the treasure was stowed; and then began the usual hunting performance, which soon resulted in the discovery of another cavity which had a very small opening.

She crept in, remained a minute, and then came out and brought her spider to this new hiding-place. The head went in easily, but it took a great deal of tugging to get the rest to follow. At last both spider and wasp were out of sight, and everything remained quiet for so long that we began to think that this time we were really to see the final act in the play. But no; when the little wasp came creeping out it was only to start off on another extended tour, in which we did not attempt to follow her. She doubtless selected another halting-place, for when she returned it was to try to get the spider out of the hole by pulling at one of its hind legs. The task, however, was not an easy one. She exerted all her strength, so that we expected to see the victim torn to pieces before our eyes, and still it did not come. At last she seemed to realize that there was more than one way to accomplish her end, and turned her attention to cutting away the earth to make

the opening larger. After a few moments' work she tried again, and although the passage was still much too small for convenience the spider was at length dragged forth, looking much the worse for wear. As she moved away we alarmed her by lifting some vines that prevented our keeping her in view, and she flew up, leaving the spider on the ground. We seized the opportunity to bend and twist the plants this way and that so that the ground might be left uncovered. The changes that we made probably disconcerted her, for she seemed to lose track of her prey. For over half an hour she hunted about, circling above the place and running around and around over the ground. She often came so close to the spider that we could not understand why she did not see it. At last it was recovered, and again she started off. We tried to follow her, but the vines were so thick that, in spite of our efforts, she soon disappeared into the undiscovered country which we had thus far been unable to penetrate.

Up to this time we had been entirely unable to understand the actions of marginatus, and each new example added to our confusion instead of clearing it away. We were inclined to think that she never made a nest for herself, but caught her spider and then hurried about for a good place to store it, and that her absurd

conduct was the result of an indecision of character which made it extremely difficult for her to choose a place and be contented with it. The last part of this judgment holds true, even now when we know her whole history, but we have at last learned that she does dig her own nest.

We had watched a wasp for some time as she carried her spider from place to place, and finally saw her take it into a crevice among some rough lumps of earth which she had previously examined. We expected one of the long spells of eventless waiting to which she had accustomed us, but on lying down and peering into the hole we found that there was an opening on the further side, for a ray of light feebly penetrated the interior. Moving about in this dim illumination was our wasp, and after a little, we could see, quite distinctly, that she was digging a hole. This then is her method — to find some sheltered hiding-place where she may secretly make her nest, that no creature may know where her treasure is hidden.

We have twice seen a marginatus pick up her spider and fly with it backward for a long distance — as much as four or five feet. This recalls the wasp which is said to fly backward before a moving horse and catch the flies that are hovering over it.

P. marginatus is not troubled by any notion as to the family connections of the spider that she takes. Anything will do provided she is strong enough to overcome it and carry it to her nest. The effect of her sting is quite variable, since in some cases the victim was killed at once, while in others it was but little affected in the beginning and lived for eighteen or twenty days.

At eleven o'clock on the morning of a warm day in mid-August we saw the steel-blue Pompilus scelestus dragging a big Lycosid across a field. The spider was sixteen millimeters long and wide in proportion, while the wasp was but thirteen millimeters long and very slender, so that the weight of the spider was at least three times that of its captor. The necessity for going backward was evident in this case, but the wasp moved rapidly considering the load that she was dragging. As she worked her way along she made frequent pauses, stopping for two or three minutes at a time in some little hollow, or under leaves or weeds. She spent a good deal of time, during these pauses, in cleaning herself, and a good deal of time also in doing something to the spider which we could not understand. She seemed to be biting the legs, near the body, beginning with an anterior leg on one side and working backward, and then repeating the operation on the other side. She went

through this squeezing process again and again, and to us it looked as though she might be trying to force back the juices from the legs into the body preparatory to cutting them off; but after a time she would seize her prey and start on again. She had made her way along in this fashion for some ten feet, when a second wasp appeared and alighted on a weed near by. This interloper was a trifle smaller than the other, and from her actions was evidently greatly interested in the paralyzed spider. When the Pompilus stopped for a moment the other moved from stem to stem in a stealthy manner just as a cat stalks a bird. The rightful owner of the prey was disturbed and dashed at her, driving her away again and again, but she flew only a short distance and was soon back, always creeping nearer and nearer to the spider. We, too, were watching with closest attention, but our desire was to see the speedy homecoming of Pompilus and to learn whether she cut off the legs of her victim; and so, interesting as was the contest between the wasp and the wasp-inquiline, we decided to interfere and remove the intruder. This was very easily accomplished, since the little insect was so intent upon following the spider that she was oblivious to our presence, and allowed us to place a bottle over her as she stood eagerly looking for a chance to advance. Her

removal gave great relief to the other wasp, as was manifested by an entire change of manner. Before, she had been constantly on the lookout, moving only with the greatest circumspection, but now she relaxed her vigilance. With the Ceropales in our vial we, too, felt relieved, and now the path of discovery seemed clear before us; but scarcely had things assumed their old status when a second enemy, a much larger and bolder Ceropales, threw both the Pompilus and ourselves into consternation. Again we took the side of our wasp and drove the other one off, but only to see it return a few moments later. The Pompilus now flew at it in a most gallant fashion and pursued it far afield, but when she came back the enemy was but a few seconds behind her. Here we again interposed and removed the second Ceropales from the field of action.

All cause for anxiety being over, the wasp now resumed her journey. Before long she came to a shallow depression in the ground which was partly sheltered by an overhanging lump of earth, and under this covering she dropped the spider and again began to squeeze its legs. After a moment she removed it to the other side of the depression, where it was subjected to further manipulation. Next, her toilet was attended to, and then the spider was carried back and placed again

under the lump of earth. At least ten times was that limp and helpless creature dragged from one side to the other of the little depression, a distance of about two inches, the time between being filled in by the wasp with cleaning herself and squeezing the legs of her victim. After forty minutes of this tedious delay the moment came when she picked up her burden with renewed determination and started rapidly on her way. We kept very close to her, but she did not allow our presence to interrupt her work, and, indeed, paid no attention to it. After she had gone along for a distance of about eight feet there was another pause, of only five minutes this time, and when she resumed her onward march it was in a new direction. Thus far she had gone almost due south, but now she turned and went six feet toward the west. Suddenly the spider was dropped. There was no hole in sight, but the wasp seemed to feel that some important crisis had arrived. Her whole manner was excited and flurried, and we thought that surely we had reached the neighborhood of the nest. How little we understood her! Her nest was still far away, and it may be that she had just begun to realize that the task she had undertaken was too heavy for her accomplishment—that at her present rate of progress her strength would be exhausted before she could

reach her goal. At any rate, something was wrong. The spider was left unprotected on the ground while she made a number of long excursions without it, sometimes being gone as much as fifteen minutes. On coming back from these trips she would return to the task of squeezing the legs with such energy and persistence that we expected to see them drop off. Then she would run over the ground in all directions, looking under lumps of earth and stones and poking her head into every little hole. Was she trying to find some suitable spot near at hand to take the place of the one which she had prepared or selected at a distance?

One hour from the time of her arrival at this place, and two hours from the time that we began to watch her, she flew away and was gone for an unusually long time. We can only suppose that when she absented herself in this way she was visiting the spot to which she wished to convey her booty. On her return she seemed to be filled with a new idea, for after climbing to the top of a tall stout weed that grew near by, she came down, seized the spider, and tried to drag it up the stem. Perhaps she meant to lift it to such an elevation that she could fly with it, but it was too heavy for her and fell after she had raised it to a height of three inches. She then flew away again, and on her return we caught

her, fearing that she was becoming discouraged and that she might presently depart to be seen no more. Had there been any prospect of her solving the difficulty that beset her our patience might have held out to the end, but this was evidently a case in which there was a failure of instinct, or intelligence, or whatever faculty was concerned.

More than a year passed before we had another opportunity of solving this problem of scelestus, and the pleasure with which we hailed her second appearance in our garden may be easily imagined. This time the wasp had made her nest, but was not ready to fill it, and when we first saw her she was running about without any particular aim in view, although at the time we supposed her to be hunting. Before long she went and took a look at the neat round hole which she had made near the fence that separates the garden from the woods. The earth that had been taken out either had been carried to a distance or had been swept away after the digging was completed, for there was no pile to be seen. This was at two o'clock of a cloudy afternoon. It may be that she needed the stimulus of sunshine to make her hunt, or perhaps she realized that what was left of the day would not give her sufficient time to capture her spider and bring it home. At any rate, she spent the

remainder of the afternoon in making short excursions around her nest, attended, at a little distance, by a smaller blue wasp, Pompilus subviolaceus, whose presence she did not seem to notice. These trips took her from ten to twenty feet from the nest, each occupying from fifteen minutes to half an hour. At every return to the nest she flattened herself out on the ground and wriggled in the dust, and then dragged herself all around it in the strangest manner. Perhaps these actions were indications of pleasurable emotion. We had seen them once before, in Prionony x atrata just before she carried a locust into her nest.

At a little after four o'clock she began to investigate, very carefully, the plants and grasses that immediately surrounded her hole, showing an especial interest in one bunch of clover that grew four inches away. Into this she finally vanished, and peering curiously among the greenery, we discovered her hanging to a leaf, which was sheltered by thick foliage on all sides. Here she remained motionless and probably fast asleep until sundown, when we left her for the night.

When we went to the garden at eight o'clock on the following morning, subviolaceus was on hand, but scelestus was still sound asleep in her leafy bower. We thought it best to awaken her, for a large spider

had spread its web just below, and if the wasp should drop upon it nothing could save her. We therefore aroused her gently, whereupon she crept slowly up the stem and, taking her stand on the highest point, surveyed the world. Then, after stretching herself sleepily, she made her toilet, cleaning off her wings and legs, and washing her face with her feet like a cat. When these duties were finished she walked slowly about for an hour, visiting her nest every now and then. Suddenly, at half past nine o'clock, her whole manner changed, and seeming very much excited she ran rapidly along, parallel with the fence, for fifteen or twenty feet, and then, rising on her wings, flew far away into the woods. She had evidently gone hunting at last, and we watched eagerly for her return. She was not successful at once, however, for at half past ten she came back without anything, stayed at the nest for a few minutes, and then flew to the woods again with the same excited manner as before. Perhaps she had already caught her spider at some far distant spot, and was getting her bearings preparatory to bringing it home ; but it was half past one when she suddenly appeared, five or six inches from the nest, coming backward through the fence, and dragging a large Lycosid. This she laid down close by, and began to bite at the

legs quite after the manner of the wasp we had seen the year before. Her movements were full of nervous excitement, in marked contrast to those of the previous day. Presently she went to look at her nest, and seemed to be struck with a thought that had already occurred to us — that it was decidedly too small to hold the spider. Back she went for another survey of her bulky victim, measured it with her eye, without touching it, drew her conclusions, and at once returned to the nest and began to make it larger. We have several times seen wasps enlarge their holes when a trial had demonstrated that the spider would not go in, but this seemed a remarkably intelligent use of the comparative faculty. Her method of work was peculiar. Standing in the tunnel with her head down and her abdomen curved under, she bit the earth loose with her mandibles and pushed it under her body and beyond the tip of the abdomen. When a little had accumulated she backed out, holding it in this way.

While she was thus employed the spider was attacked by a very tiny red ant, that could not by any possibility have stirred it. When the wasp caught sight of this insignificant marauder she fell into a fit of wild fury, and bending her abdomen under, seized the ant again and again in her mandibles, and flung it backward

against the tip of her sting. The little creature finally escaped, seeming none the worse for the rough handling to which it had been subjected, while the wasp, still trembling with excitement, grasped her spider and rushed off to a distance of several feet, carrying it up on a weed and depositing it there. The labor of excavation was then resumed, and after a half-hour's work the nest was completed to her satisfaction.

Coming up head first, she flattened herself out on the ground, and sprawling thus, dragged herself all around it. The spider was now brought to the nest, being left once on the way while she ran in and out again, and was taken in after a new and original fashion. Backing in herself, she seized it by the tip of the abdomen and dragged it down without any trouble, since the legs were gently pushed up over the head and made no resistance.

In two minutes she emerged from the opening, and standing on the four posterior legs, with her abdomen hanging down into the hole, scratched the earth backward with the front legs and mandibles. As it fell in she pushed it down with the abdomen, and as the hole filled she raised herself higher and higher on her legs, still using the tip of the abdomen to work the material into place.

When the filling of the nest was nearly completed, we caught the wasp, and after taking the spider, threw back the earth into the hole. Subviolaceus, who had watched the homecoming from a respectful distance, now felt that her turn had come, and descending upon the spot began to dig. Not finding anything, she shifted her position several times, and worked industriously, even returning after we had frightened her away. Sharp says that a Ceropales has been observed to oviposit on a spider, not while it was being carried in, but subsequently by entering the nest for the purpose; and the actions of subviolaceus pointed to similar intentions on her part. We have watched her for an hour at a time running into the open nests on the Bembex field, sometimes coming out again directly and sometimes remaining inside for several minutes. It is not likely that she would utilize the flies of Bembex, but it may be that she was looking for the Pompelid nests that are often made in the same locality. Scelestus did not notice subviolaceus, and it is difficult to see why a wasp should be disturbed by the presence of a parasite. In making and storing her nest she is the blind instrument of an impelling power; she knows what she must do, but not why she does it. Her descendants are in most cases as completely outside of her experience

THE HOME-COMING OF SCELESTUS

as her ancestors, and how should she guess that the presence of a certain fly or wasp means danger to her race? Of what happens to her egg after she leaves it she is so absolutely ignorant that she might easily look on with serene indifference at the destruction of her own larva by that of the intruder. In Astata we see, as might be expected, a calm tolerance of the visits of the Chrysis fly, but the uneasiness of scelestus herself at the sight of Ceropales and the valorous defense of Trypoxylon show more highly developed instincts. Bembex, too, deeply resents the presence of parasites, although after the deed is done she feeds their young without questioning their right to her care. Among bees, Andrena, and Nomada, which is parasitic upon it, are said to live on most friendly terms; but in other genera there is a deep-seated enmity between host and parasite.

In the literature of the Hymenoptera references have been made from time to time to certain wasps that cut off the legs of spiders or other creatures before storing them away; but observations on the subject have been rare and not very definite. Brehm, in the "Thierleben," says that Agenia punctata builds nests of mud, and places in each cell one moderately large spider from which she has first removed all the legs. The

most interesting notes on the subject have been made by M. Goureau, who gives an account of finding two spiders that had been mutilated by wasps, one of them having had all of the legs cut off, and the other all but the first pair. At another time a wasp that was flying near him let fall a spider, which he captured before it could be recovered by the owner. The wasp escaped, so that he could not determine the species, but the spider's legs had been removed. He concluded that instead of stinging the spiders the wasps had mutilated them so that they could not run away. He does not seem to realize that death would certainly result from such an operation.

Vespa germanica often cuts off the wings of a dead wasp, or even cuts its body into two parts, before flying away with it, but this is only when the captured insect is too large to be handled in any other way; and Pompilus fuscipennis sometimes cuts off one or more legs from her spider, although without any regular method of procedure.

Agenia bombycina finds a nesting-place to her liking on our smoke-house, in the crevice between the bricks and the wooden door-frame, where she makes clusters of little mud cells, putting one mutilated spider into each, and storing about one a day. Her locality sense

is unusually poor, owing apparently to her intense nervousness and excitability, but some individuals are better endowed than others in this respect.

NEST OF AGENIA BOMBYCINA

On a bright morning in the middle of August we stationed ourselves by the smoke-house at eight o'clock, and half an hour later an Agenia began to bring lumps of earth, working out of sight under the door frame. She kept at it steadily, spending three or four minutes in getting a load and one or two in placing it. At twelve o'clock, her nest being ready, she flew away to hunt for a spider. So long as a wasp comes and goes at frequent intervals time slips away rapidly, but to keep one's attention unflagging through hours of watching is weariness to the flesh. We saw no more of our Agenia until three, when she appeared, half walking, half flying through the grass, going forward. Her spider was held by the spinnerets, and being larger than she was it trailed behind her. On reaching the wall she began to climb; but the weight of the spider made her fall again and again, and forty

LYCOSA KOCHII, FOUND IN NEST OF AGENIA BOMBYCINA

minutes passed in wearisome toil before it was safely put away. The egg having been laid, she began to bring earth for closing, and we felt thankful that our task as well as hers was nearly over. She worked slowly now, taking ten or fifteen minutes for a trip; but after bringing in the sixth pellet she took on a livelier air, and before long we were convinced that she had begun to build a new cell. For two hours longer we watched her unremitting labor, and when we left her at six o'clock she was flying back and forth as briskly as ever.

Another Agenia, less ambitious, brought her spider at three o'clock and then went to bed in an empty cell, head in, tail sticking out. We cut away a section of the door-frame that covered the spot without disturbing her slumber. This one could never remember where her nest was, but had a long hunt for it every time she brought a pellet; and when she had caught the spider she lost herself completely on the brick wall, going to the very top, and even around the corner on to the side of the building. Every little while she would fly back to the grass at the threshold and start up afresh, and in this way she finally stumbled on the right spot by accident. This seemed very stupid of her, as she made many locality studies. Her behavior was in striking contrast to little Rhopalum's

unerring choice of one tiny pin-hole among hundreds just like it.

The larva of bombycina cocoons nine days after the egg is laid. The spiders that we found in the cells were dead even when taken on the day of storing. There was no rule about the degree of mutilation, one having seven legs left, two five, one two, and four none. We have no doubt that the object of this curious habit is to save room in the nest.

Chapter X

THE ENEMIES OF THE GRASSHOPPER

EARLY in September a little black Tachytes suddenly became very common in the garden. The first one that we saw was going forwards in a series of long jumps, carrying a small grasshopper which was held by the base of the antennæ. She soon doubled on her tracks, and it became evident that she did not know her way; but after going about in circles for two minutes she ran into her nest. When she came out she spent a long time in circling around, flying close to the ground in wavy, snaky lines, occasionally alighting to run a few steps; but in spite of this locality study, ten minutes later, when she came jumping along with her second grasshopper, she had lost her nest again and hunted about just as before, twice going directly over it without seeing it. While she was thus occupied another wasp of the same species attacked her and tried to get possession of the grasshopper, but the rightful owner was able to defend it. At last it was stored away,

and she proceeded to fill the nest, scratching the earth in with her first legs and working it down with the tip of the abdomen. She worked quietly but steadily for

TACHYTES

ten minutes, closing the place neatly, and then brought bits of leaf and pieces of earth to cover it all over.

On the same afternoon we saw another of these wasps digging her nest, but she was so much disturbed when we came anywhere near her that we were obliged to retire. On the next day we saw her astride of a small grasshopper, jumping along like the one of the day before. She too had great trouble in finding her way. When she reached the nest she laid her prey down while she went inside for a moment, and then, coming

out, seized it by the antennæ and backed in with it, instead of taking it in forwards as was done in the other case.

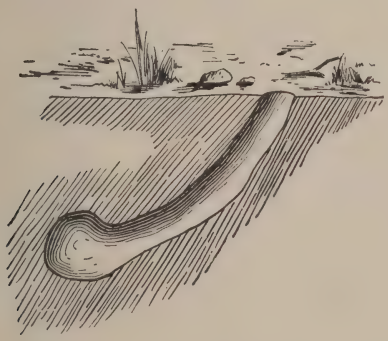
Another wasp of this species carried a much larger grasshopper, which was so heavy that she could not jump with it, but was obliged to keep to the ground. In this case only one was used instead of two, which is the usual number. This wasp was first seen at a distance of twenty feet from her nest, and yet she went straight to the right spot without the least confusion, showing that some individuals of the species have a better idea of locality than others.

The nest is a short, shallow tunnel with an enlargement at the end, within which are placed the grasshoppers, on their backs, with their heads in. Earth is packed solidly into the tunnel, but not into the cavity at the end.

We took two eggs of this species. Each was placed across the thorax of the grasshopper at the base of the neck, on the ventral side. Both hatched at the end of thirty-six hours from the time they were laid, ate for three days, and then spun their cocoons. One of them ate only one small grasshopper, leaving a second one untouched, while the other finished the large grasshopper that formed her sole provision.

The grasshoppers taken from the nests, five in number, were in all cases alive, there being a quivering of the mouth parts, and in some cases of the legs also, without any stimulation. This condition lasted for twenty-four hours from the time the poison was injected. After that they became quiet, but remained alive until they were destroyed by the larvæ.

It is a curious thing that in these wasps is found the perfection of that method of paralyzing the prey which is so much dwelt upon by Fabre, although from their habits this fine workmanship is not of the slightest use



NEST OF TACHYTES

to them. They entomb their victims underground, where the conditions are favorable to their preservation, and the extremely short period that elapses between

the laying of the egg and the spinning of the cocoon makes it a matter of indifference whether the grasshopper is alive or dead, since in any case it would be eaten before decomposition set in.

We deserve no credit for discovering a second species, Tachytes peptonica, for by her loud buzzing, slow flight, and persistent hovering over the nest she gave us every assistance in her power. She looks and acts like one of the large leaf-cutting bees, and this resemblance is heightened by the fact that the grasshopper which she carries is frequently of a leaf-green color. Her nest, which is sometimes on the bare ground and sometimes in the grass, has no external sign to mark it, and when with a great deal of fuss and buzzing she descends and burrows, it closes behind her and disappears from view, so that unless one marks the exact spot there is no way of detecting it afterward. On her exit a very slight amount of scratching closes the hole and leaves it looking exactly like the surrounding surface; so that in comparing her work with the protracted labor of Ammophila and some species of Pompilus in disguising the locality of the nest, we were struck by the success to which she attained with a very trifling amount of effort.

It takes peptonica thirty or forty minutes to catch

a grasshopper, and at each visit she remains for ten or fifteen minutes inside the nest. The grasshopper is carried in the mandibles, supported by the second and third pairs of legs. We never succeeded in opening a nest of this species, but a grasshopper taken as the wasp was bringing it home did not die until the sixth day.

In our summer work we often found ourselves wishing that we could be in half a dozen places at once and could chase several wasps at the same time. Never did we feel these desires more keenly than on the twenty-ninth of July, when, after spending the best part of an hour in watching the hunting of an Ammophila, we were obliged to choose between following her to a possible conclusion, and giving our attention to a little jet-black wasp, Lyroda subita, which we now saw for the first time. This wasp was running around a bunch of clover in a nervous, agitated manner, as though she were oppressed by some great anxiety. The chance of discovering something entirely new decided us to relinquish our Ammophiline hopes, and we sat down at the feet of our new teacher.

We could not see anything remarkable about that bunch of clover, but certainly the spot had some strong attraction for the uneasy little wasp. She ran off first in one direction and then in another. She circled about

and made short flights now this way and now that, but always returned. At last she betrayed the secret of her interest by descending to the ground and picking up a small black cricket which had been lying close by all the time. She flew up into the air with it, but even now did not leave the neighborhood, continuing to fly about from place to place, alighting now and again on the bean plants.

After this performance had lasted for five minutes she brought her burden back to the same spot that it had occupied before, laid it down, and without vouchsafing to us any explanation of her conduct, began to burrow into the soft earth. She went down head first, backing out with the dirt, which she carried with the front legs. While she was thus occupied we defended her booty against two hunting parties of ants which, at different times, fell upon it and would certainly have carried it off if we had not been at hand.

It took the wasp twenty minutes to open the burrow, although, as we afterward learned, it had been excavated before. At the end of that time she turned around inside, came out head first, and dragged the cricket within.

We at once opened the nest, but found it impossible to follow the tunnel on account of the crumbling of

the earth. Indeed, we almost concluded that we were doomed to complete failure, for it was not until we had gone down between six and seven inches that we found, in a little pocket, our wasp in company with three crickets, upon one of which was a larva a day or two old. At the time we knew nothing of the habits of Bembex spinolæ, and we were much astonished to find a wasp which evidently fed her young from day to day.

The contents of the nest were carefully conveyed to our wasp-nursery at the cottage. The cricket that we had seen taken in was dead, as was also the one upon which the larva was feeding. The third one was alive, as was shown by a rhythmic movement of the palp on the right side. By the next day, however, this one also was dead.

On the morning of the third day, July thirty-first, the larva had eaten all of the first cricket and the greater part of one of the others, leaving only the large hind legs. Supplying the place of the mother, we killed two more and put them into the tube. One of these was eight millimeters long, this being about the size of those which the wasp herself had caught, while the other was of another species and much larger, being thirty millimeters long. Its size and kind, however, made no difference to the larva, which attacked this one next, although there were two small ones yet untouched. It ate only

half of this big one, however, and then passed on. On August second we gave it two more small crickets, and for that day and the one following its good appetite continued, but on August fourth it stopped eating. We thought that its larval life must be completed, and expected to see it spin its cocoon, but something was lacking which we were too ignorant to supply, and on August fifth it died. It had eaten six small crickets and half of the large one, which was equal to about two more. Thus ended our only acquaintance with this interesting little wasp.

The second week of August furnished such good play in our garden that island life was neglected; but one brilliant morning we rowed over to the home of Bembex and Philanthus, hoping that something new was in store for us. We were not disappointed, for as we climbed the crest we met a splendid Chlorion cœruleum dressed in shining blue, cricket in mouth, plunging down the hillside through the long grass. Twenty-five feet below, she reached her underground home, vanished for two or three minutes, and then, coming to the entrance, turned her head from side to side as though listening. Some indiscreet insect was chirping loudly not far away, and before long the wasp ran out into the grass, flew to a stump, dropped to the ground, flew to the top of a tall

CHLORION AND THE INDISCREET CRICKET

weed, dropped again, and ran into a hole. A moment later she came out, dragging a very limp cricket. An ant that crossed her path was chased vindictively, and then the cricket was placed on its back and scraped from head to foot four or five times with the mandibles. She then ran a little farther, laid it down again, and repeated the operation, after which it was taken into the nest.

To find ourselves on the track of a lively wasp at the beginning of her day's work was great good luck, and as Madam Cœruleum was perfectly fearless and did her hunting on foot, instead of disconcerting us with the long flights by which many of our wasps made the chase hopeless, we had every chance to learn her ways.

It was a fatal day for the crickets. Between nine o'clock and one, sixteen had been packed away, enough to provision three cells, as we knew from former observations. Her manner was brisk and energetic, as she ran about poking her head into every likely hole. At one time we saw her dislodge a cricket which tried to escape by hiding under some brush. She pursued, there was a lively scrimmage, and it was pulled out quite limp and was then held in the mandibles, back up, while she gave it a prolonged sting under the neck, after which

it was carried home without further manipulation. At another time she paused in her home-coming to give the victim one long squeeze at the neck. The crickets were placed in pockets, neatly arranged on their backs with their heads inward and their long legs projecting into the main tunnel. They were alive when taken, but died from day to day in the laboratory, the larvæ eating them in this state without criticism.

While we were watching we noticed a much smaller wasp hovering about, and presently she slipped into the nest. When the owner returned and found her, there was a slight commotion in the passage-way, and then the inquiline appeared, shaking her wings in a flippant manner, as though she cared nothing for an encounter with the Big Blue. Instead of coming out immediately as usual, cœruleum stayed inside for twenty-five minutes. We should like to think that she was occupied in finding and destroying the egg of the parasite, but we have no reason to suppose that she could recognize that menace to her fortunes.

Cœruleum lives in her nest and enlarges it from day to day to fit her necessities. On going over to the island one morning we found a cricket sleeping calmly in the entrance way, little guessing how dangerous was its position. It did not budge until the wasp came creeping up

from below, when it jumped away to a place of safety. Before the day's hunting began, a long study of the locality was made on foot, tufts of grass, weeds and stones being carefully noted, and this accounts for the ease with which the nest is afterward found.

One July afternoon we saw a little red Tachysphex tarsata on the Bembex field of the island. She had a very anxious air, and was running about wildly and rapidly, holding a small grasshopper with the third pair of legs. She let it drop four or five times, and when she picked it up again she seemed to sting it, but of this we were not quite certain. At last she left it and began to rush about, investigating the Bembex holes, entering one of them and perhaps throwing out a little dirt as though she intended to use it, and then hurrying off to another. We have no doubt that her confusion was the result of her having lost track of a hole that she had made, as was the case with P. quinquenotatus in one of our earlier observations. The Pompilus, after a long search, resigned herself to the necessities of the case and made a new nest; but this little wasp could not adjust herself to a break in the system of her instinctive activities, and at last deserted her prey and disappeared. We waited for an hour; and then, as she did not return, we took possession of the grasshopper. It gave no

response to stimulation and never revived, a very careful examination later showing that it was quite dead.

On the next morning we again saw this wasp on the Bembex field. She was looking for a nesting-place, and when she had selected one she began to work; the weather was warm and sunny, so that the Bembecids were in the full swing of their obstreperous activity, and perhaps resenting the presence of the little red wasp, or perhaps in a spirit of teasing, they kept snatching her up and carrying her off to a distance of two or three feet. She took these interruptions with the most philosophic composure, hurrying back to her work as soon as she was released, without any display of resentment. When the nest was finished, she made a careful locality study both on foot and on the wing and then flew away. In twenty minutes she came back, apparently to refresh her memory, for she again made careful notes of all the points that could help her to identify the place. She dug a little more and then departed, to return five minutes later, on foot, with a grasshopper. In spite of all the precautions she had taken, at this exciting moment she was unable to remember just where her nest was, and spent some time in running wildly about, but when she did find it she went in without delay. We caught her as she came out, and dug up the grasshopper,

but found no egg, so that she probably would have brought in a second victim had we let her go. The tunnel ran in obliquely for an inch and a half, the pocket at the end being two inches below the surface.

A few days later we saw Larra quebecensis, another little grasshopper wasp, with the same red abdomen as tarsata, going to and fro about her nest, occasionally throwing out a little sand. She ran about near by all through the afternoon, but was not in a mood for work. On the next morning at ten o'clock, we found her touching up the nest a little, after which she left it open and flew away. In an hour she came leaping along like Tachytes, holding a small grasshopper in the third legs. This was placed inside the door while she turned around, and was then pulled in. She came out immediately, and in twenty minutes brought a second, and in ten more a third grasshopper, staying within this time for some minutes, after which she closed the nest. We took out the grasshoppers, one of which bore an egg underneath, in the middle, in front of the first pair of legs. The grasshoppers lived for five, six, and seven days, but the egg did not develop. We once saw a quebecensis that had laid down her grasshopper while she hunted for her nest. She was moving in sinuous lines up and down the face of a cliff, with incredible rapidity; we

could not distinguish her, but could see only a black streak with an occasional flash of crimson. When she rises on her wings, too, she is wonderfully quick, disappearing as if by magic, it being quite impossible to even guess at the direction she is taking.

Chapter XI

WORKERS IN CLAY

THE nests of Pelopæus cœruleus and Pelopæus cementarius, our two mud-daubers, are common under eaves and in other sheltered places, and many a country boy on opening them has been astonished to find that they do not contain wasps, but are crammed with spiders. Let them alone, however, and the wasps will arrive, for somewhere in the mass is an egg; and when it hatches the spiders will serve as breakfast, dinner and tea for the larva, until the change from the Arachnida to the Hymenoptera has been accomplished. Poor spiders! it is a wonder that there are any left, such thousands and tens of thousands are destroyed by these tremendously energetic enemies.

Of what is Pelopæus thinking as, humming loudly, she jams her paralyzed and benumbed victims into her little cylindrical tubes? If only we could get inside of that little head! If only we could be wasps for a day, and then come back and tell about it, how much vain speculation would be saved! We can understand her

when she soars gayly into the blue, the sunshine flashing from her brilliant wings; we too have felt the delight of health and freedom. She is still comprehensible when, at the close of day, she and her sisters quarrel for the favorite sleeping-places among the carvings of the porch pillars; but we cannot follow her mental processes when, at the moment of building, she surrenders herself to the mysterious sway of instinct, doing she knows not what, but doing it joyously, and preserving through it all the precious possession of her own individuality. Every aspect speaks of pleasure as these wasps gather at well or spring, and, singing contentedly, stand on their heads to gather their loads of mud. Briskly and gayly they fly back and forth, pausing at the nest long enough to pat the soft building material into shape. A single load makes half a ring at the larger part of the nest or a whole one at the bottom; and since one dries before the next is put on, the contour of each ring is visible when the tube is done, giving a very artistic effect. This is only accident, however; the wasp cares nothing about the beauty of the structure, for her next step is to daub the whole with lumps of mud, the walls being thus thickened and strengthened. About forty loads are necessary for each cell, and to build and provision one is a good day's work.

It is strange enough that with no one to teach her Pelopæus knew how to make her cell; but now she must do her hunting, and it is stranger still that she should be impelled to catch nothing but spiders. How does she know a spider from a fly, and why should she prefer one to the other? Not so unreasonable as some wasps, however, she demands nothing further than that her prey shall belong to this great group, and passes lightly over differences of species and genera. Her powerful sting fits her to cope with anything she may meet; but as the size of the cell must be taken into consideration, and the victim must be carried home on the wing, she is on the lookout for something not too large. Here then she ceases to be an automaton, and to some extent makes use of her wits.

How does Pelopæus seize her spider? When and how many times is it stung? Is the wound given with discrimination, a certain point in the ganglion being pricked, so that the spider may be paralyzed, but not killed? Is there any malaxation?

These were important questions to us, and we were therefore greatly excited over our first hunt. One of the blue wasps came flying along, alighted on our cottage wall, and began her search, creeping into corners and cracks and investigating cottony lumps of web.

In a few moments a small Epeira strix (the only species to be found on the cottage) was dislodged, and at once dropped to the floor of the porch. The wasp paid no further attention to it, but went on with her search. Three more spiders, one after the other, were disturbed and dropped to the floor without being followed. The fifth one discovered was a little larger than the others, and was seized by the jaws and first legs of the wasp before it had time to escape. It was then rolled into a ball, or at least so it appeared, and stung, then rolled a little more and stung again, and then carried off. We had scarcely drawn breath after this performance when a second wasp appeared. This one dislodged two spiders, and then caught a third, which was seized and stung without any rolling, and then instantly borne away. A third wasp seized the first spider that she found, and started on her flight at the same moment, stinging it on the wing.

So the game went on, while we waxed warm with the excitement and fascination of the chase. As the hours went by some of the yellow mud-daubers appeared, adding to the interest of the scene, although we could not see that their method differed in the least from that of cœruleus.

Rarely did they succeed in catching a spider until

they had dislodged two or three. Sometimes the spiders were followed as they dropped, and were caught on the floor, but oftener the wasp let them escape and continued her search on the wall. At the moment of capture we could see that she bent her abdomen under and inflicted a sting, but although we concentrated our attention on the point we could not be sure as to just what part was touched. It is our impression that this first sting was given anywhere, at random, with the object of producing a condition of temporary quiet in the victim, so that the next part of the operation could be carried on with deliberation.

The second step in the procedure was commonly for the wasp to alight upon some neighboring object, usually the branch of a bush or tree, and sting the spider a second time, being evidently in no haste; but the difficulty of following her as she flew, and her habit of alighting above our range of vision, made it almost impossible to see just what she did. She certainly remained on the branch for some moments, either resting quietly or rolling the spider around and around, and had every opportunity to sting it as carefully as she wished; but we afterward found that she followed no exact method, since two thirds of the spiders were killed at the moment of capture, and most of the others

died within a week, while a few lived for thirty-five or forty days. In this study we opened five hundred and seventy-three cells and handled over two thousand spiders, watching over them from day to day with a magnifying glass, that no sign of life might be neglected.

When Pelopæus has filled her cell, she seals it up and makes another close to it, clusters of from six to twenty being found in one spot. Any especially desirable place is used by great numbers; and they make a lively scene, working eagerly at their nests, dashing off for more mud or bringing in their victims. All animated by the same compelling instinct, they are still individuals, and the character of each enters into her work. One picks up the first spider she sees, no matter how tiny it may be, and makes twenty-five or thirty journeys before her cell is filled, while another seems to have a calculating turn of mind, using four or five big spiders instead of a quantity of small ones. Has she made a note of the calibre of her cell, and determined to save herself trouble by looking farther and selecting the largest ones that will go in?

Most of them place their cells vertically; but a few prefer the horizontal position, while still others, undecided as to the matter of direction, make clusters in which some are horizontal and others upright. Occa-

sionally there is a remarkable innovation in building-material, as where in a group of fifteen, four cells in the centre were constructed of pure white plaster, forming a striking contrast to the surrounding mud color. One wasp built an entire cluster after an original fashion, following the beaten track until the cell was completed, and even bringing mud enough to daub it over, as her sisters were doing, but sticking it all in one spot, so that when the group was complete irregular lumps were attached here and there, leaving visible the elegant architecture of the individual cells. Did she think they were too pretty to spoil? or was she merely one of those radical spirits that rebel against conventionality and demand change for the sake of change? It is these variations that furnish Natural Selection with its materials; but rigid as may be the rules regarding the non-survival of the unfit, we find that the race of Pelopæus still produces many absent-minded wasps, that after spending hours in carefully constructing their nests, seal them up empty, forgetting to put in the spiders or to lay the egg.

HORIZONTAL CELLS OF THE MUD-DAUBER

When a cell is sealed, the mother wasp ceases to take an interest in it, but she has done all that is necessary. In two or three days the egg hatches, after which the larva spends ten or fifteen days in eating, and then spins its cocoon. Here it remains, perhaps for only a few weeks, — for there are two or three generations in one season, — or perhaps through the long months of winter.

Fabre gives a most entertaining account of a French species of Pelopæus which nests in the wide-mouthed chimneys of the peasant. Undisturbed by the steam of washing day or the bustle of dinner-getting, the wasp enters the open door, passes unconcerned among the human inhabitants, and makes her cells against the smoky bricks, out of reach of the flames. This species kills her prey at the moment of capture, by which act she falls in the estimation of Fabre, who respects a wasp in proportion to the nicety with which she delivers her sting. He says, however, that at least she follows a logical method in turning to account these spiders, menaced with early decay. In the first place the prey is multiplied in each cell. The piece actually attacked by the larva is soon a disorganized mass, likely to decay speedily; but it is small and is consumed before decomposition can advance, for when a larva once attacks a

spider it does not leave it for another. The others then remain intact, which is enough to keep them fresh during the short period of larval life. When, on the contrary, the prey consists of a single large piece, it is necessary that the organic life should be maintained, and a special art must also be observed in eating it. It is well then that Pelopæus is inspired to take numerous small pieces. The egg, moreover, is always placed on the first spider brought in, whether the storing of the nest is completed within a few hours, or whether, as in some cases, it occupies several days; and this M. Fabre considers a very happy arrangement.

The French Pelopæi differ from ours at nearly every point. Ours kill only about two thirds of their victims, many of the others being paralyzed so perfectly that they live for two or three weeks. Again, ours, instead of placing the egg upon the first spider, almost invariably lay it upon the last one brought in. Another point of difference is that our larvæ frequently start in by eating up the soft abdomens, like children who first devour the plums in their pudding, returning later to the tough parts that are left, a rash and reprehensible course of action of which their better-taught French cousins are never guilty. When one comes to compare the two sets of facts furnished by the two groups of species, the

deductions which Fabre has drawn as to the importance of the instincts of the French group are seen to be unfounded. The American species violate nearly every principle which he considers necessary to their existence, and yet they flourish and multiply. For our part we find nothing in the actions of Pelopæus that needs to be explained — nothing that is not well adapted to the conditions under which each species works. The measure of praise or blame which we mete out to these depredators is merely a way of saying whether we would or would not follow their methods in provisioning our houses and rearing our children. Perhaps we would always use large spiders and would always have them fresh; but it is evident that tastes differ, and the matter is so purely a subjective affair that it will have to go unsettled. In any event, whether her victims be strong or feeble, old or young, big or little, fresh or dry, they certainly serve admirably in enabling Pelopæus to rear brood after brood, and to people the different parts of the earth with abundant representatives of her kind.

Chapter XII

SENSE OF DIRECTION

WE once made a number of experiments to discover in what way the social wasps came back to the nest on returning from their hunting expeditions. Were they endowed with some innate power which made memory of places unnecessary, and enabled them to fly in a straight line to any point they wished to reach, or did their return depend upon the more commonplace method of remembering the appearance of the countryside?

One morning at half past eight, we placed a wasp cage over the opening of a yellow-jacket hole that had been closed since the night before, and caught fifty-five workers, after which the nest was again closed, one of us taking the cage out on to the lake, while the other remained to watch for their return.

At seven minutes before nine, twenty of the wasps were liberated an eighth of a mile from shore near the end of the island. All, without exception, flew toward

the island and away from the nest. Whether they settled could not be determined. The boat was then moved an eighth of a mile beyond the island to the north, where, at ten minutes after nine, the remaining wasps were set free. They seemed a good deal confused, and flew in all directions. Many returned to the boat and alighted, but soon flew away again. Two that settled on the boat were knocked into the water; but they instantly rose and circled up into the air until out of sight.

Of the fifty-five wasps that we set free, thirty-nine returned to the nest by ten o'clock, five of them belonging to the lot that flew to the island, since they soon found their bearings and came directly home, reaching the nest before the wasps of the second lot were liberated.

Of the thirty-five wasps that were set free at the second point, at least twenty started in wrong directions. Adding these to the first twenty, we have left only fifteen that appeared to know where to look for their home, and yet thirty-nine reached the nest in a little more than an hour from the time the first wasps were set free.

On another morning we caught thirty-eight workers and took them to a boat-house on the shore of the lake, in the second story of which was a large room with two

good-sized windows; one looked west over the lake and away from the nest, the other east toward the nest, and both were wide open. The west window was the brighter, but the other was light, the sun being on that side of the house.

We placed the cage in the middle of this room and opened the door, stationing ourselves well to one side so as not to interfere with the movements of the wasps. They came out very naturally, pausing a moment before flying, and followed each other so slowly that we could easily see which window they went out by. Twenty-two flew through the west window away from the nest, and sixteen through the east toward the nest.

At another time we took fourteen wasps from the nest of a different species and carried them seventy-three yards to the southeast. The cage was opened so that they could fly out in any direction they chose, and they all started in a straight line for the nest. Later on the same day, we took forty-five from this nest, and set them free one hundred and seventy-six yards to the south. Seven flew north toward the nest, twenty-one south, eight west, and seven east, while the other two circled around as they rose higher and higher, until they were lost to view. None in this experiment returned to take a fresh start.

Again, we took twenty-three wasps three hundred yards southeast of the nest and liberated them in an open field ; thirteen flew east or south away from the nest, seven west or northwest toward the nest, and four returned to the starting-place and seemed unwilling to venture out again.

These observations show that the two species of wasps with which we experimented have no sense of direction in the form of a mysterious additional sense, nor yet in the form of a power by which they keep a register of the turns and changes in a journey and are thus able to retrace their way. Our cage was of wire, and so open that they could see all about, as we carried them from place to place; yet when they flew out, they most frequently started in a wrong direction and toward a point that we had not passed. In many instances, however, these wasps returned to the nest, and it seems highly probable that as they rose higher and higher into the air, circling as they went, they discovered some lofty treetop or other object that had before served them as a landmark, and that in this way they were able to make their way home. Bee-keepers know that if young workers which, in strong hives, pass the first ten or fifteen days of their lives in feeding the larvæ without going abroad, are taken out and set free only a short

distance from home, they are unable to find their way back, and perish, while those that have passed beyond the nursing stage and have begun to do outside work may be carried long distances away and still readily regain the nest.

With the solitary wasps we attacked the problem from the other end. We observed what the social wasps did in attempting to return to the nest; with the solitaries, we watched them when, after making the nest, they prepared to leave it to go out into the fields or woods in search of food or prey, thinking that the procedure of different species under these circumstances would afford a clue to the faculty upon which they depended to find their way about. If they were furnished with an innate sense of direction they would not need to make a study of the locality of the nest in order to find the way back, but if they were without this sense it would be only common prudence to take a good account of their bearings before going far afield.

The sight of a bee or a wasp returning to its home from some far distant spot, without hesitation or uncertainty, is indeed marvelous. When we saw our first Ammophila perform this feat we were filled with wonder. How was it possible for her to hunt for hours, in all directions, far and wide, and then return in a direct

line to a nest which had been so carefully covered over that every trace of its existence was obliterated?

To say that she is a creature of instinct, however, is not quite fair to her ladyship's intelligence, as a better acquaintance with her would prove. In reading much popular natural history one might suppose that the insects seen flying about on a summer's day were a part of some great throng which is ever moving onward, those that are here to-day being replaced by a new set on the morrow. Except during certain seasons the exact opposite of this is true. The flying things about us abide in the same locality and are the inhabitants of a fairly restricted area. The garden in which we worked was, to a large extent, the home of a limited number of certain species of wasps that had resided there from birth, or having found the place accidentally, had settled there permanently. To make this matter clear let us suppose the case of an individual of A. urnaria. In June she spent her time in sipping nectar from the onion flowers or from the sorrel that grew on the border of the garden. In July came the days of her courtship and honeymoon, and these too were passed in going from flower to flower, from one part of the garden to another. Many a day we have followed her when she flew from blossom to blossom along a row of bean plants, turning, when

she reached the end, and wending her way leisurely back along the next row. Then comes a day when we see her running over the ground and looking carefully under the weeds for a good nesting-place. At last a spot is selected and she begins to dig; but two or three times before the work is completed she goes away for a short flight. When it is done, and covered over, she flies away, but returns again and again within the next few hours, to look at the spot and, perhaps, to make some little alteration in her arrangements. From this time on, until the caterpillars are stored and the egg laid, she visits her nest several times a day, so that she becomes perfectly familiar with the neighborhood, and it is not surprising, after all, that she is able to carry her prey from any point in her territory in a nearly direct line to her hole — we say nearly direct, for there was almost invariably some slight mistake in the direction which made a little looking about necessary before the exact spot was found.

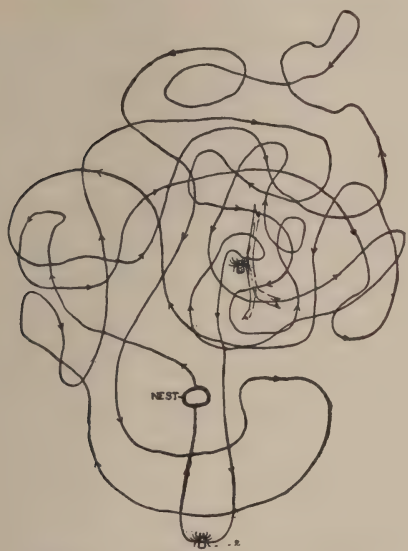
After days passed in flying about the garden — going up Bean Street and down Onion Avenue, time and time again — one would think that any formal study of the precise locality of a nest might be omitted; but it was not so with our wasps. They made repeated and detailed studies of the surroundings of their nests.

Moreover, when their prey was laid down for a moment on the way home, they felt the necessity of noting the place carefully before leaving it.

Of the species that catch their prey before making the nest we have good examples in Pompilus quinquenotatus, the tornado wasp, and fuscipennis, the Pompilus with the red girdle.

The tornado wasp may make her nest anywhere from one to ten feet from the spot on which she has deposited her spider, while fuscipennis never goes more than fourteen inches away. During the process of excavation both of these wasps pay several visits to the spider, and frequently they have difficulty in finding it. As an example of this kind of trouble we give a diagram of the course followed by an individual of fuscipennis after she had finished her nest, in trying to find her spider and in bringing it home. This and the other similar diagrams that are given are reductions of large tracings that were made on the spot. Although not absolutely correct they are exact enough for all practical purposes, since wherever there is an error it is necessarily in the direction of making the path pursued by the wasp appear shorter and less complex than it really was. The individual in question had placed her spider on a cucumber vine which lay on the ground, not hidden by

leaves, but fully exposed to view. The nest was only eight inches away, but when it was finished and the



COURSE FOLLOWED BY POMPILUS FUSCIPENNIS IN FINDING HER SPIDER AND IN RETRACING HER STEPS TO THE NEST [1]

wasp went to bring the spider, she found it only after a search of three minutes; and then when she went

[1] The nest being completed, the wasp went skimming over the ground as indicated by the line, until the spider, which had previously been stung and placed upon a leaf, was found. She then dragged it some distance beyond the nest to the point 2, from which place she took it to the nest.

back to the nest she at first passed to one side and went some inches beyond, so that she had to retrace her steps.

Marchal notes that some wasps are very unskillful in finding their way about, showing by their errors and hesitations not only that they have no sense of direction, but that they are badly served by their memory and by what senses they have. He draws this conclusion from his own observations, one of which had for its subject Pompilus seriaceus, which nests, conveniently for him, in the walls of the rustic summer-house which he uses for a laboratory. A wasp of this species, having caught her spider, had a most wearisome experience in getting it to the nest, which had been previously excavated near the ground. She first carried it straight up, not only passing the opening, but going to the very top of the wall. Realizing that she had gone wrong, she laid it down, and after a prolonged hunt up and down, to the right and to the left, found the nest; but on leaving it again to go for the spider, she started in exactly the wrong direction, down instead of up; and not until forty minutes had been spent in searching alternately for spider and for nest did she finally bring the two together.

The best evidence that wasps depend upon a know-

ledge of the place in returning to their nests is given by the pains they take to acquire that knowledge. When Sphex ichneumonea was ready to dig her nest, she had great difficulty in finding a place that suited her. Many a spot was merely looked at and passed by, while others that seemed more attractive were left after they had been excavated for a little way. At last, the nest dug, she was ready to go out and seek for her store of provisions; and now came a most thorough and systematic study of the surroundings. The nests that had been partly made and then deserted had been left without any circling. Evidently she was conscious of the difference and meant, now, to take all necessary precautions against losing her way. She flew in and out among the plants, first in narrow circles near the surface of the ground, and now in wider and wider ones as she rose higher in the air, until at last she took a straight line and disappeared in the distance. Very often, after one thorough study of the topography of her home has been made, a wasp goes away a second time with much less circling or with none at all.

If the examination of the objects about the nest makes no impression upon the wasp, or if it is not remembered, she ought not to be inconvenienced nor thrown off her track when weeds and stones are removed

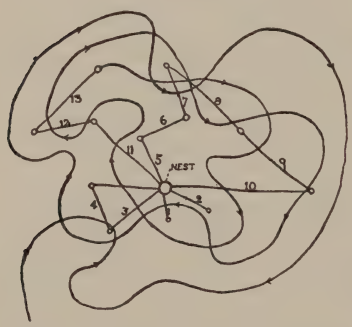
and the surface of the ground is smoothed over; but this is just what happens. Aporus fasciatus entirely lost her way when we broke off the leaf that covered her nest, but found it, without trouble, when the missing object was replaced. All of the species of Cerceris were extremely annoyed if we placed any new object near their nesting-places. One Ammophila refused to make use of her burrow after we had drawn some deep lines in the dust before it. The same annoyance is exhibited when there is any change made near the spot upon which the prey of the wasp, whatever it may be, is deposited temporarily. We learned from experience how important it was not to disarrange the grass or plants on such occasions. The wasps are in many cases so prudent as to conceal their booty among the leaves; and this made it very inconvenient to keep our eyes upon the captured prey, as was quite necessary if we wished to follow it on its travels. To avoid the discomfort of lying on the ground or of twisting the neck at some impossible angle for half an hour at a time, we sometimes gently moved the intercepting objects to one side; but even such a slight change cost us dear in time and patience, as it threw the wasp out of her bearings and made it difficult for her to recover her treasure. We recall one exceedingly warm day in September when we were

delayed in this way for forty minutes, when she would have seized the spider and gone on her way without a pause had we not interfered.

Very often the wind would shake the plant so that the spider or caterpillar would fall to the ground. Under these circumstances the wasp was not at all disconcerted, but, on not finding her prey where she had left it, dropped at once to where it was lying. This is probably only an extension of their ordinary habits. A wasp that takes spiders learns to follow them as they drop from the web on being disturbed. In this they are evidently guided by sight, but perhaps they are also aided by the sense of smell under other conditions, — to the extent, at least, of recognizing the place upon which their prey has lain. With so much to build upon, it is easy to see how natural selection may have perfected the habit. We are delaying a long time over details, but we feel that to invoke an unknown sense is permissible only after a careful study of the daily life of the animals in question has left the problem unsolved.

Among the wasps that first make the nest and then provision the larder, Astata bicolor is one of the most interesting. She makes a permanent abiding-place, and probably uses it until all of her eggs are laid. It is evident that since she comes and goes many times

during the several weeks of her occupation, she does not need to make a prolonged study of the environment at every departure. Her first survey, just after the nest is completed, is most thorough; and, as a usual thing, when she first comes out on each succeeding morning, she reviews the situation more or less carefully. Individuals differ in this respect, however, some studying their local habitat much more than others. In this as well as in all other matters our observations are in complete accord with those of Sir John Lubbock, who says: "Indeed, many of my experiences seem to show not only a difference of character in the different species of ants, but that even within the limits of the same species

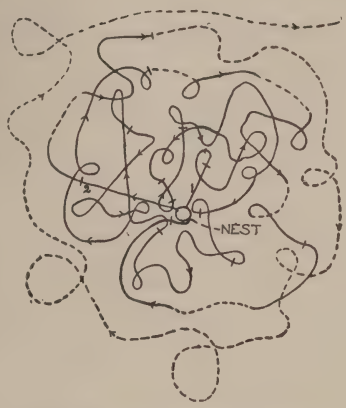


LOCALITY STUDY OF ASTATA BICOLOR [1]

[1] The wasp flew from nest to 1, paused a moment, then flew back; then to 2, paused and flew back; then to 3, paused, then to 4, paused and flew back to nest; flew to 4, 5, 6, 7, 8, and 9, pausing at each spot, and flew back to nest along 10; flew, successively, along 11, 12 and 13, resting at the spots designated; from 13 she circled around nest in direction of arrow points and departed.

there are individual differences between ants, just as between men." [1]

This little bug-hunting Astata bicolor made her study in a different way from Sphex ichneumonea. She first flew from the nest to a spot near by and settled there, returning, after a moment, to the nest, or else flying to another resting-place. After pausing in a number of places (in the case of the one followed in the diagram, thirteen), she finished by a rapid zigzag flight. Another wasp of this genus, unicolor, differed from bicolor in not returning to the nest from the different resting-places, and in



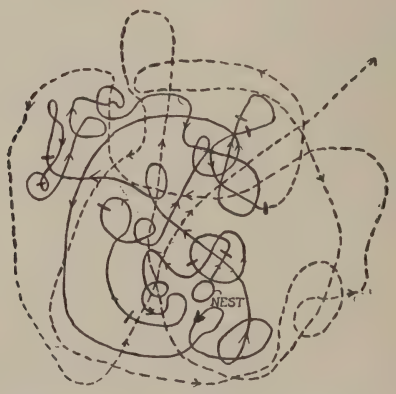
LOCALITY STUDY OF ASTATA UNICOLOR [2]

[1] *Ants, Bees, and Wasps*, p. 95.

[2] The continuous line shows the course walked over by the wasp, the short marks at right angles representing resting-places; the broken line indicates flight. Line 1 shows the first study, leading back to the nest, and line 2 the second, ending in flight and departure.

walking from one to another of them instead of flying, although the last part of the study was made on the wing.

Cerceris deserta was one of the wasps that objected strongly to our presence, and she also made a great deal of fuss about leaving her nest. Nearly all the species circle before leaving a spot to which they intend to return, but deserta begins her flight with a series of



SECOND LOCALITY STUDY OF A. UNICOLOR[1]

short zigzags in the form of a half circle on one side of the nest. C. nigrescens, too, begins with semicircles, while C. clypeata flies entirely around and around the

[1] The continuous line shows the course walked over by the wasp; the short marks at a right angle indicate resting-places; the broken line indicates flight.

opening. The contrast between the deliberate movements of Astata and the rapid flight of Cerceris is very striking.

We have now given a sufficient number of instances, from widely separated genera, to show the care that is taken by wasps to acquaint themselves with the surroundings of their nests. It has also been shown that in spite of all this care they frequently have trouble in finding their way about. All these facts have led us to conclude that wasps are guided in their movements by their memory of localities. They go from place to place quite readily because they are familiar with the details of the landscape in the district they inhabit. Fair eyesight and a moderately good memory on their part are all that need be assumed in this simple explanation of the problem.

Chapter XIII

INSTINCT AND INTELLIGENCE

OUR study of the activities of wasps has satisfied us that it is impracticable to classify them in any simple way. The old notion that the acts of bees, wasps, and ants were all varying forms of instinct is no longer tenable, and must give way to a more philosophical view. It would appear to be quite certain that there are not only instinctive acts but acts of intelligence as well, and a third variety also — acts that are probably due to imitation, although whether much or little intelligence accompanies this imitation is admittedly difficult to determine. Again, acts that are instinctive in one species may be intelligent in another, and we may even assert that there is a considerable variation in the amount of intelligence displayed by different individuals of the same species. We have met with such difficulty in our attempts to arrange the activities of wasps in different groups that we are forced to the conclusion that any scheme of classification is merely a convenience, useful for purposes of study or generali-

zation, but not to be taken for an absolutely true expression of all the facts. This kind of perplexity is well understood and allowed for in all morphological work, but it has never been fully realized in the study of habits. The explanation is not far to seek. The habits of but few animals have been studied in sufficient detail to bring out the evidence that there is as much variation on the psychological as on the morphological side, although this field seems fresh and inviting when compared with the researches of the laboratory.

The necessity of interpreting the actions of animals in terms of our own consciousness must be always with us. To interpret them at all we must consider what our own mental states would be under similar circumstances, our safeguard being to keep always before us the progressive weakening of the evidence as we apply it to animals whose structure is less and less like our own.

We arrange the activities of the wasps that we have studied into two groups, Instincts, and Acts of Intelligence, it being understood that these classes pass by insensible stages into each other, and that acts that are purely instinctive when performed for the first time are probably in some degree modified by individual experience. In this classification the question of origin is not considered. The facts are grouped under the

two heads, the inferences that they warrant being left for later consideration. Under the term Instinct we place all complex acts that are performed previous to experience and in a similar manner by all members of the same sex and race, leaving out as non-essential, at this time, the question of whether they are or are not accompanied by consciousness. Under Intelligence we place those conscious actions which are more or less modifiable by experience. It is this power that enables an insect to seek, accept, refuse, choose, — to decline to make use of this or to turn to account some other thing. Many writers prefer the term Adaptation for these activities, and it possesses certain advantages. With these definitions in mind, let us group the activities of wasps under the two heads.

With the wasps of the genus Pelopæus we were present on several occasions when the young emerged from the pupa case and gnawed their way out of the mud cell. They were limp, and their wings had not perfectly hardened, and yet when we touched them they tried to attack us, thrusting out the sting and moving the abdomen about in various directions. These movements were well directed, and, so far as we could observe, quite as perfect as in the adult wasp. Stinging, then, is an instinctive act.

The particular method of attack and capture practiced by each species in securing its prey is instinctive. Ammophila pricks a number of ganglia along the ventral face of the caterpillar; Pelopæus, we believe, stabs the spider in the cephalothorax, and probably the several species of Pompilus do the same. Astata bicolor adopts the same tactics in capturing her bugs, while it is said of the flycatchers that they commonly overcome their victims without using the sting. It is by instinct, too, that these wasps take their proper food supply, one worms, another spiders, a third flies, moths, or beetles. So strong and deeply seated is the preference, that no fly robber ever takes spiders, nor will the ravisher of the spiders change to beetles or bugs.

PARALYZED SPIDER HUNG UP ON SORREL BY QUINQUENOTATUS WHILE SHE DIGS HER NEST

The mode of carrying their booty is a true instinct. Pompilus takes hold of her spider anywhere, but always drags it over the ground, walking backward; Oxybelus clasps her fly with the hind legs, while Bembex uses the second pair to hold hers tightly against the under side

of her thorax. Each works after her own fashion, and in a way that is uniform for each species.

The capturing of the victim and caring for it before the hole is made, as in the case of P. quinquenotatus, or the reverse method, pursued by Astata, Ammophila, Bembex, and others, of preparing the nest before the food supply is secured, is certainly instinctive; as is also the way in which some of these wasps act after bringing the prey to the nest. For example, S. ichneumonea places her grasshopper just at the entrance to the excavation, and then enters to see that all is right before dragging it in. Under natural conditions this order is never varied, although the wasp can adapt herself to different circumstances when occasion demands. Again, we see Oxybelus scratching open her nest while on the wing, and entering at once with the fly held tightly in her legs. Each way is characteristic of the species, and would be an important part of any definition of the animal based upon its habits.

The general style of the nest depends upon instinct. Trypoxylon uses hollow passages in trees, posts, straws, or brick walls; Diodontus americanus, a member of the same family, always burrows in the ground, as do Bembex, Ammophila, and Sphex. In the case of Trypoxylon the passage may be ready for use or may require more

or less preparation ; the instinctive part is the impulse that requires the insect to use a certain kind of habitation. Any one familiar with T. rubrocinctum would never look for her nest in standing stems or under stones; to use Mr. Morgan's test, he would be willing to bet on the general style of the dwelling-place. All of these acts are similarly performed by individuals of the same sex and race, not in circumstantial detail but quite in the same way in a broad sense. Variation is always present, but the tendency to depart from a certain type is not excessive. In Cerceris the burrow is tortuous, this style of work being common to many species in the genus, and very characteristic. No Sphex nor Ammophila constructs any such tunnel. The adherence of all the members of a species to a certain style of architecture is, then, due to instinct.

The spinning of the cocoon, in those species in which the larva is protected in this manner, and its shape, are instinctive. We find that closely allied species in the same genus make very different cocoons, as is seen in T. rubrocinctum and T. bidentatum. Some wasps spin no such covering for themselves. It is a well-known fact that silkworms sometimes omit the spinning of a cocoon ; but this does not affect the argument, since the descendants of these individuals make the charac-

teristic covering. Such cases are probably due to individual variation or perhaps to atavism, this throwing back being not uncommon among forms that are well known.

Not all of the instinctive acts here enumerated are displayed by each species studied, although they are common to most of them. We have doubtless overlooked some activities that should come under this head, as we have not made a thorough study of any sufficient number of species to make a final settlement of the matter.

As we have seen with Ammophila and Pelopæus, faults of instinct are not uncommon, but of all our wasps the one that shows the greatest aberrations is Pompilus biguttatus. The sandy beach of Lake Michigan is a favorite nesting-ground with this species, and is the scene of many a bold robbery, since they are unprincipled little wretches and

> ". . . the good old rule
> Sufficeth them, the simple plan
> That they should take who have the power
> And they should keep who can."

We once found an unusually tiny biguttatus vainly trying to drag a large Epeirid which her sting had reduced to helplessness. It was as though a feeble child

should try to move the body of an elephant. The little wasp clasped one of the spider's legs firmly in her mandibles, and then with braced feet and the wildest flutter of wings made gallant but futile attempts to get it started. Now she lost her hold on the ground, and wings and legs were all whirling desperately in the air. Now her feet grasped a loose ball of earth, and, feeling that something was moving, she renewed her efforts. The pellet was drawn nearer and began to rotate around the wasp, while she seemed to be under the impression that she was moving forward. After a few minutes of vigorous exercise, she paused, perhaps to see how she was getting on, and the bit of earth rolled away; so that when the attack was renewed, it was under the old discouraging conditions. She was the impersonation of perseverance and energy; but after half an hour (no one knows how long she had been at it before we came) she gave it up, and with many reluctant circlings flew away. It was probably experiences of this kind that developed in some of her relatives the habit of digging the grave under the victim, and thus saving the trouble of transportation.

At another time, we saw a biguttatus trying to run backward with a little bit of a spider, which she had lifted from the ground and was carrying in her man-

dibles,—trying to run backward, because it is the rule with this genus to move in that way when encumbered with a load, it being easier to drag a heavy spider than to pick it up and go forward. The wasp in question was drawn in two directions. Instinct made her go backward, although in this particular case it was needless, while she felt a constant desire to turn and go straight ahead. As a result she waltzed slowly over the sand in a series of overlapping circles, her head turned toward every point of the compass in succession, a kind of progress most amusing to the lookers-on.

Biguttatus is not strong enough to fly when laden, but it is the habit of the species to climb backwards to the top of every obstacle in the path, and from this vantage point to gain time by taking a downward flight in the direction of the nest. It is only in the case of tall, smooth-stemmed plants and grasses that the advantage gained is enough to repay the trouble of climbing, and we have often thought that the notion costs the wasp more trouble than it is worth, — as was certainly the case with one comical little creature that carried the idea to the extreme of folly. Not only did she scale objects in her way, but just as old Dr. Johnson felt that he had to touch every tree and post as he walked along, so when this wasp saw, out of the corner of her eye, a

stone or a plant three or four inches to one side, it called upon her to climb, and climb she did, although she was obliged to leave her proper path to do it.

It is obviously more difficult to distinguish actions of intelligence than of instinct. One must be familiar with the normal conditions of the insects in question before he is able to note those slight changes in the environment that offer some opportunity for an adaptation of means to ends, or before he is competent to devise experiments which will test their powers in this direction.

We find two classes of intelligent actions among the Hymenoptera which are sufficiently distinct to be considered separately, although, like all natural groups, they grade into each other. The first of these includes those actions that are performed by large numbers in a similar fashion under like conditions, while in the second class each act is an individual affair, — as where a single wasp, uninfluenced in any way by the example of those about it, displays unusual intelligence in grappling with the affairs of life. Examples of the first class are found in such modifications of instinct as are shown by Pelopæus and other wasps in the character of their habitations. Pelopæus, instead of building in hollow trees or under shelving rocks, as was the ancient custom of the race, now nests in chimneys, or under the eaves

of buildings. We have found T. rubrocinctum taking advantage of the face of a straw-stack that had been cut off smoothly as the cattle were fed through the winter. The same power of adaptation is shown by Fabre's experiment with Osmia, in which he took two dozen nests in shells from a quarry, where the bees had been nesting for centuries, and placed them in his study along with some empty shells and some hollow stems. When the bees came out, in the spring, nearly all of them selected the stalks to build in as being better suited to their use than the shells. All of these changes are intelligent adaptations to new modes of life, serving to keep the species in harmony with its surroundings. The same thing may be seen when a number of social wasps work together to replace the roof of their nest when it has been torn off.

An instance of the second class is seen in one of our examples of Pompilus marginatus. This species, while searching for a nesting-place, leaves its spider lying on the ground or hides it under a lump of earth, in either of which positions the booty is subject to the attacks of ants; the wasp in question improved upon the custom of her tribe by carrying the spider up into a plant and hanging it there. We have now and then seen a queen of Polistes fusca occupy a comb of the previous year

instead of building a new one for herself, — showing a better mental equipment than her sisters who were not strong-minded enough to change their ways, and so built new nests alongside of unoccupied old ones which were in good condition. In Bembex society it is good form to close the door on leaving home, but sometimes a wasp will save time by leaving the entrance open. This, however, is a doubtful case, as the advantage would, perhaps, be more than balanced by the exposure of the nest to parasites.

Some years after our first experience with Pompilus scelestus we saw a wasp of this species carrying her spider home. She dropped it close to the nest, and looked meditatively, first at the hole and then at the spider. It was unquestionably going to be a very tight fit, but if she could get it in that would be an advantage; so after a moment she seized it by the tip of the abdomen and backing down tried to pull it after. Tug — *tug!* No, it would not go down, and scelestus pushed it out and carried it to a place of safety up among some clover blossoms. She then washed and brushed herself neatly, and took several little walks, so that it was fully fifteen minutes before she began to enlarge her nest. All that time she must have carried in her little scrap of a mind the idea of doing a necessary act which was outside of

her ordinary routine; and we noted with interest that the change when it was made accomplished exactly what was needed, — the spider went in, but not too easily.

In an experiment with a French Sphex which has the habit of laying her cricket down at the threshold, and going inside for an instant before dragging it in, Fabre took advantage of the moment that the wasp was out of sight below to move her prey to a little distance, with the result that when the wasp came up she brought her cricket to the same spot and left it as before, while she visited the interior of the nest. Since he repeated this experiment about forty times and always with the same result, it seemed fair to draw the conclusion that nothing less than the performance of a certain series of acts in a certain order would satisfy her impulse. She must place her prey just so close to the doorway; she must then descend to examine the nest; and after that she must at once drag it down, any disturbance of this routine causing her to refuse to proceed. We once found a Sphex ichneumonea at work storing her nest, and thought it would be interesting to pursue Fabre's method and find out whether she were equally persistent in following her regular routine. We allowed her to carry in one grasshopper to establish her normal method of procedure, and found that, bringing it on the

wing, she dropped it about six inches away, ran into the nest, out again and over to the grasshopper, which she straddled and carried by the head to the entrance. She then ran down head first, turned around, came up, and seizing it by the head, pulled it within. On the following day, when she had brought a grasshopper to the entrance of the nest, and while she was below, we moved it back five or six inches. When she came out, she carried it to the same spot and went down as before. We removed it again, with the same result, and the performance was repeated a third and a fourth time, but the fifth time that she had found her prey where we had placed it she seized it by the head, and going backward dragged it down into the nest without pausing. On the next day the experiment was repeated. After we had moved the grasshopper away four times, she carried it into the nest, going head foremost. On the fourth and last day of our experiment, she replaced the grasshopper at the door of the nest and ran inside seven times, but then seized it and dragged it in, going backward. How shall this change in a long-established custom be explained, except by saying that her intelligence led her to adapt herself to circumstances? She was enough of a conservative to prefer the old way, but was not such a slave to custom as to be unable to vary it.

"It hath been an opinion," says Lord Bacon, "that the French are wiser than they seem, while the Spaniards seem wiser than they are." We leave it to our readers to determine whether the wasps are wiser than they seem or seem wiser than they are.

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The Riverside Press
Electrotyped and printed by H. O. Houghton & Co.
Cambridge, Mass., U. S. A.

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